Participatory appraisal for farm-level soil and water conservation planning in West Usambara highlands, Tanzania

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EROAHI Report 2

The work reported in this book has been carried out as part of the project 'Development of an improved method for soil and water conservation planning at catchment scale in the East African Highlands' (EROAHI). This project was funded through the Dutch/Swiss 'Fund for Methodological Support to Ecoregional Programmes', and the Dutch 'Partners for Water Programme'.

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Dedicated to my late parents

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Chapter 1

INTRODUCTION

Introduction

Soil erosion is one of the most important and challenging problems facing farmers and natural resource managers worldwide (Lal, 1995; Pimentel, 1995; Stroosnijder, 1995). Because of soil erosion, vast areas of once fertile lands have been rendered unproductive. It is estimated that of the world's total land area of 13.4 x 10^9 ha, about 2.0 x 10^9 ha is degraded to some extent (World Resources Institute, 1993). Asia and Africa combined account for a total of 1.24 x 10^9 ha of the degraded land, with water erosion the most prominent degrading process (UNEP, 1993). According to Lal (1995), by the year 2020, yield reduction due to soil erosion may be as much as 16.5% for the African continent and about 14.5% for sub-Saharan Africa. Regardless of the methods used in the assessment of these rates, the message is clear: the situation is alarming worldwide and something must be done.

Soil erosion is also one of the major threats to agricultural production in Tanzania (Mushala and Forser, 1992; Tenge et al., 1998; Kaihura et al., 1999). The West Usambara highlands are among the areas mostly affected by soil erosion in Tanzania; here, soil erosion is resulting in an annual loss of fertile topsoil of about 100 t ha^{-1} and consequently reducing crop yields (Pfeiffer, 1990; Shelukindo and Kilasi, 1993; Kaswamila, 1995; Lyamchai et al., 1998). Soil and water conservation in the West Usambara highlands has a long history (Liversage, 1944; Semgalawe, 1998). Conservation measures introduced in the area include bench terraces, strips of Napier grass *(Pennisetum purpureum)* or of Guatemala grass (*Tripsacum laxum)* and different forms of agroforestry. The Soil Erosion Control and Agroforestry Programme (SECAP), Traditional Irrigation Programme (TIP) and the African Highland Ecoregional programme (AHI) have also introduced different improved erosion control measures, such as multipurpose trees, crop strips along the contours, bench terraces, *fanya juu*[1] infiltration ditches and cut-off drains (Shelukindo, 1995; AHI, 2000).

Despite the considerable efforts that have been undertaken to control soil erosion in the Usambara highlands and Tanzania in general (Kimambo, 1990; Mshana, 1992; Jones, 1996), the adoption of soil and water conservation measures is still minimal and soil erosion continues to be a problem, causing loss of the fertile topsoil. The costs of this erosion are the reduced crop yields, food deficiency, silting-up of waterways, damage to various structures and loss of land value (Buch, 1983; Lyamchai et al., 1998; Meliyo et al., 2002). Past efforts in soil and water conservation in the West Usambara highlands have not been successful, mainly because of the top–down approach that neglected farmers' knowledge and their participation in planning, and because the financial implications of the proposed SWC measures were not considered at the planning stage (Conte, 1999; Johansson, 2001; Mowo et al., 2002)

[1] **Fanya juu** are hillside ditches within the field at specified intervals made by throwing the excavated soils on the upper part of the ditch. They reduce the speed of the runoff and trap eroded soil. Eventually the trapped soil forms a terrace.

The catchment approach

Following the failure and experiences of the top–down approaches to enhance adoption of SWC measures, a catchment approach (CA) was adopted (Thomas et al., 1997; Kiara et al., 1999; Kizughuto and Shelukindo, 2003). The basic principle underlying the CA approach is the participation of all stakeholders in the planning of SWC. Soil conservation is approached by considering a focal area – the catchment – regardless of individual farm boundaries. The CA involves mobilization of the community through different Participatory Rural Appraisal (PRA) tools (Theis and Grady, 1991; Kirway et al., 2003). In the CA, a multidisciplinary team of professionals, farmers and other stakeholders are involved in participatory appraisal in which different constraints are identified and ranked in order of priority. The time set to address soil erosion problem in a particular catchment is up to two years (Kizughuto and Shelukindo, 2003). Because of the nature of soil erosion and its related problems that are not directly observed and may take a long time to be observed, only in rare cases do soil erosion and conservation rank high among the priority problems in these PRA meetings. The time set to address soil erosion and conservation in a particular catchment is also too short to observe the effects. As a result, the successes of CA have been observed only in areas where the community already knew the problems of soil erosion, could visualize the benefits of soil conservation and were willing to participate.

A review of the CA in SWC planning (Admassie, 1992) identified three shortcomings, which, if improved, will increase the success of the CA. First, the extent and quality of the involvement of the communities is not encouraging; agricultural extension officers are still leading the community using their own experiences and their own criteria. Secondly, quantification of the actual soil and water loss is often not carried out, hence the demonstration effects of soil erosion and benefits of conservation are not observed and therefore do not convince farmers to invest in SWC. The third shortcoming of CA is that the economics of soil and water conservation often do not play a role in the planning of soil conservation measures, with the result that farmers do not realize the costs and benefits of SWC measures before these are implemented.

Participatory appraisal of SWC measures

Proper planning of SWC should include examining the SWC options and all their relevant aspects to see if they contribute towards the pre-set objectives. This is important because investment in SWC competes with other activities for scarce resources of labour, equipment and land. The benefits of SWC are not directly observable; they differ among farmers and may take long time to be realized. Methods that help farmers in identifying effective and efficient SWC measures are therefore desired, to ensure farmers properly allocate their resources. To determine and assess the relevant benefits and costs of a project, before the implementation an appraisal with the use of cost-benefit analysis could be applied (Kuyvenhoven and Mennes, 1989).

The main objective in SWC is to increase agricultural production while minimizing soil loss to an acceptable level (physical effectiveness). However, for the SWC measures to be attractive, their costs should not exceed the benefits (financial efficiency). Appraisal of SWC should therefore not only consider the effectiveness of the proposed measures in reducing soil loss and increasing agricultural production, but also whether the costs are affordable and the benefits exceed the costs for the respective farmer groups. Translating the erosion losses and benefits of soil and water conservation measures into economic terms will motivate farmers, policy makers and other actors to invest in soil erosion control measures (Graaff, 1996; Lal, 1998).

So far, no simple tool has been available for an easy prediction of the profitability of the recommended conservation measures. Such a tool should be developed with the farmers, in order to adequately consider their perception about and assessment of the various cost and benefit categories. Farmers have good knowledge of their environment through experiences obtained by observing changes that have occurred over time because of soil erosion. The use of this knowledge can lead not only to the active participation of farmers, but also to better understanding of the design of appropriate SWC measures. The use of farmers' indicators of soil erosion enables farmers to lead the process of identifying eroded fields and the extent of soil erosion problems in the catchment. After the soil erosion problem has been identified and perceived by farmers, the available SWC options need to be evaluated on the basis of criteria set by farmers themselves and other stakeholders. This should lead to the selection of potential SWC measures that are suitable for each group.

Lack of information on the physical effectiveness of different soil conservation measures for major soils, climates and management practices aggravates the problem of translating the erosion losses and benefits of conservation into economic terms (Kaswamila, 1995; Lal, 1995). It is important first to identify the social and economic factors that influence the adoption of soil and water conservation measures, and then to develop a participatory methodology for the assessment of the physical effectiveness and the financial efficiency of soil and water conservation measures.

The financial implications of the SWC alternatives need to be known by individuals or groups of farmers, so that before the implementation it is understood what costs will be incurred and what benefits can be expected. Farmers and other stakeholders should integrate financial analysis the non-financial criteria identified.

Such farm-level soil and water conservation planning should be undertaken in close collaboration between farmers, extension officers and other important local stakeholders. This planning methodology should focus both on the participatory assessment of erosion and on the physical and financial feasibility of soil and water conservation measures. The result should be a simple tool for participatory appraisal of farm level soil and water conservation planning, which is the subject of this thesis.

The EROAHI project

The research described in this thesis was conducted as part of the EROAHI project titled "Development of an improved method for soil and water conservation planning at catchment scale in East African highlands". EROAHI aimed at developing an improved soil and water conservation planning method by incorporating farmers' indigenous knowledge, the quantification of erosion effects, and financial analysis of soil and water conservation measures. The project was conducted in two sites representative of the East African highlands: Kwalei catchment in the West Usambara highlands, Tanzania and Gikuuri catchment in Embu district of the Central Highlands of Kenya.

Most of the research was conducted in Kwalei catchment, which is representative of the soil degradation in the West Usambara highlands and is the benchmark site for the African Highlands Ecoregional Programme in Tanzania (AHI).

The overall goal of the EROAHI project was to improve the CA. The specific objectives were:

1) to develop field-scale indicators of erosion and sedimentation based on indigenous knowledge of soil and vegetation characteristics;
2) to attach quantitative values of erosion, sedimentation and/or productivity to the developed indicators, based on field scale measurements;
3) to quantify erosion, sedimentation and soil productivity at catchment scale, using the developed indicators, and to compare the estimates with a detailed model study to develop simple "rules of thumb" for erosion assessment;
4) to develop a methodology for the financial appraisal of planned soil and water conservation measures at farm level;
5) to further develop a specific methodology for catchment-scale soil and water conservation planning in the East African highlands using a participatory approach

While the subject of this thesis is closely related to most of these objectives, the focus is on the last two objectives. Other objectives are dealt with in detail and reported by Okoba et al. (2005).

The project area

The West Usambara highlands are located in northeastern Tanzania in Lushoto district, Tanga region. The district lies between latitude 4°22′ and 5°08′ and between longitude 38°5′ and 38°38′. It has an area of about 3500 km^2 out of which 2000 km^2 are arable land and 340 km^2 are forest reserve. The West Usambara highlands have good climatic conditions that have attracted not only farm communities but also tourists, and the area provides agricultural products to the population within and outside the highlands. The highlands are also the sources of streams that are used for irrigation in the lowlands and for the generation of hydro-electricity (Mowo et al., 2002).

According to Pfeiffer (1990), Lushoto district can be subdivided into four Agro-Ecological Zones: The Humid-Warm Zone, The Dry-warm Zone, The Dry Cold Zone and The Dry Hot Zone. These zones differ in altitude and amount of annual rainfall, but they have common problems of soil degradation due to soil erosion. Kwalei catchment forms part of the humid warm zone of the West Usambara Highlands. This zone covers the south, southeast and central parts of the Lushoto district; it is situated at 800-1500 m a.s.l. and has an annual rainfall of 800-1700 mm. Cash crops in this zone include coffee, tea, and vegetables. Food crops include maize, bananas and beans.

The major economic activity in the West Usambara highlands, on which over 90% of the population depends, is agriculture (Shelukindo and Kilasi, 1993; Lyamchai et al., 1998). Most of the agricultural activities are on steep slopes and on the valley bottoms where irrigation for horticultural crops is possible. The West Usambara highlands are experiencing stress in terms of decline in farm size and crop production due to population pressure and land degradation. According to the URT (2002), the population in these highlands is estimated at 418,652 people and the annual growth rate is 2.8%, giving a population density greater than 100 people km^{-2}. This population density makes the West Usambara highlands the most densely populated area in Tanzania.

The population pressure has increased demands for food, fuel wood, construction materials and other socio-economic needs. In order to meet these demands, forest has been cleared and agriculture has expanded onto marginal areas with steep slopes. Population pressure has also caused land fragmentation to uneconomical size, and fallowing is no longer possible. Farmers cultivate on hill slopes (18-60%), repeatedly clearing and burning the vegetation; this leaves the soil bare or with very little ground cover. In some places animals graze freely on the steep slopes. These practices encourage soil erosion, consequently leading to loss of agricultural productivity and other off-site effects. It is estimated that about 84% of the original forest has been cleared. Landlessness is also becoming a common phenomenon, fuelling migration to the lowlands and urban centres (Johansson, 2001; Mowo et al., 2002).

Research objectives

The major objective of the research was to design and apply a methodology for assessing the physical effectiveness and financial efficiency of different soil conservation measures in the West Usambara highlands in Tanzania. This would result in a simple tool for the participatory appraisal of soil and water conservation measures for planning at the farm and catchment scales.The specific objectives were:

1) to identify social and economic factors that influence the adoption of soil and water conservation in the West Usambara highlands.
2) to assess the physical effectiveness of the soil and water conservation measures used in the West Usambara highlands.
3) to analyse the costs and benefits of major soil conservation measures for major farm patterns.
4) to develop a simple tool for the financial appraisal of conservation measures.

Thesis outline

This thesis is the result of a multi-stage assessment of soil and water conservation measures as used in the West Usambara highlands. The thesis is organized in six chapters, as outlined below.

The social and economic setting of the research area was investigated, including farmers' knowledge and factors that influence their decision to implement certain SWC measures (Chapter 2). The methods used were group discussions, household survey and transect walks. In total, 104 households were interviewed using a pre-designed survey form, and fields were visited during the transect walks. Extension staff serving the twelve villages in the catchment was also interviewed, to obtain technical information. Cluster analysis was used to group the farmers and examine the characteristics that can make these farmers interesting for the implementation of SWC measures. The farmers were grouped according to household characteristics such as sex, education, marital status and family composition, but also on the basis of resources availability, such as farm size, land tenure, possession of livestock, farm income, labour availability and involvement in off-farm activities. The influence of the external factors such as contacts with extension agents, SWC programmes and exchange visits was also analysed. Adoption of SWC measures was analysed in terms of the proportion of farmers undertaking the measures and in terms of the area covered. Socio-economic factors for adoption were analysed by factor analysis and chi-squared methods.

The physical effectiveness of SWC measures and the farmers' preferences for SWC measures were assessed, to identify to what extent the measures fulfil the objective of reducing soil erosion and to what extent they are in line with farmers' preferences and other socio-economic factors influencing adoption (Chapter 3). The first step in this assessment was to do an inventory of SWC measures used. The inventory was done through group discussions, household survey and field visits. Farmers mentioned SWC measures and the criteria they use for the implementation. They ranked the importance of the SWC measures according to their own criteria. Field experiments using Gerlach troughs and erosion plots were established, to assess the physical effectiveness of the three SWC measures ranked highest by the farmers: bench terraces, *fanya juu* and grass strips. These measures were compared with the "without conservation" situation in terms of reduction of soil loss and surface runoff, the retention of soil moisture, and the impacts of these on maize and bean yields. The experiments were conducted in the long and short rainy seasons of 2002 and 2003. During the field experiments, farmers were involved in assessment by pair-wise ranking of the measures according to crop performance and erosion indicators such as rills, and broken SWC structures after rainstorms.

In Chapter 4, the financial results of the establishment of bench terraces, *fanya juu* and grass strips are analysed for farmers with three opportunity costs of labour, five slope classes and two soil types. Farmer groups were established based on characteristics identified in Chapter 2. Slope classes and soil types were based on the field and soil surveys conducted in the catchment. Financial analysis involved the Financial Cost–Benefit Analysis (FCBA) method. Erosion effects and benefits of SWC measures (Chapter 3) were translated into financial terms in relation to social and economic factors (Chapter 2). Future costs and benefits of SWC measures were converted to their present value using three discount rates. The efficiency of SWC measures under different physical and socio-economic conditions was analysed with FCBA, considering various values and combinations of slopes, soil types, labour costs and discount factors.

Following the financial analysis, an integrated evaluation of SWC measures was performed using Multi-Criteria Analysis (MCA) based on all information gathered on effectiveness and financial efficiency and other social and economic aspects (Chapter 5). The main stakeholders in the catchment were identified through Participatory Rural Appraisal (PRA). These were farmers and the government agents dealing with agricultural extension, forest and agricultural research. Through group discussions and household surveys, both the farmers and the government agents set the objectives and the criteria they would use to evaluate SWC measures. Farmers determined the relative importance of each criterion during the group discussion, by pair-wise ranking. Government officials used an indirect ranking method by assigning weights to each criteria based on their experiences. SWC alternatives to achieve the objectives were discussed during village meetings attended by both farmers and government agents. In order to rank the SWC measures according to the criteria and preferences for each stakeholder, the effects of the SWC alternatives were required. Impacts on the physical effectiveness and financial efficiency criteria were obtained from the respective results of physical effectiveness (Chapter 3) and financial efficiency (Chapter

4). The impacts on other criteria could only be expressed in qualitative terms and therefore ranking was applied.

In Chapter 6, an improved approach using farmers' soil erosion mapping and a financial analysis tool is described and applied in the planning of SWC measures. The erosion-mapping tool is based on farmers' knowledge of changes in soil surface and crop characteristics. Farmers use these characteristics as indicators of soil erosion and to classify and map erosion status at field and catchment scales. A farmers' erosion map was discussed during the village meeting and used to identify severely eroded areas and to plan soil and water conservation. The financial analysis tool was developed using data from the field experiments to determine the effectiveness of SWC measures (Chapter 3), information obtained from extension officers dealing with SWC and information from farmers who had been implementing SWC measures for a long time. Socio-economic data for the financial tool were obtained from the detailed financial cost–benefit analysis of SWC measures (Chapter 4). With the help of the erosion map, farmers whose fields needed conservation selected SWC measures for implementation on their fields. The financial analysis tool was then applied, to determine the financial costs and benefits of the selected options. Farmers were involved in financial analysis by providing the specific input information and discussing the results for each option they selected. Eventually, farmers identified the option (s) feasible to their physical and socio-economic conditions. Both the erosion map and the financial analysis results for individual farmers were presented and discussed at the village meeting, which was attended by most farmers in the catchment.

The conclusions and a summary are presented in Chapter 7 and 8. A guideline in the form of a manual for future participatory appraisal of SWC measures, using financial cost–benefit analysis, is presented as an annex. This manual is to be used by extension staff working with farmers in a participatory way.

Limitations of the research

The findings of this thesis on the methods and application of participatory appraisal of SWC measures for farm-level planning in Kwalei catchment in the West Usambara highlands, Tanzania, could, after some adjustment, be extrapolated to other East African highland areas with similar biophysical and socio-economic settings. Because of the differences in farming environment, however, generalization to wider areas should be done with caution, after the results presented here have been supplemented with further studies. Soil erosion and soil conservation has both on-site and off-site effects. Only the on-site aspects are dealt with in this research and the only types of SWC measures dealt with in this research are those commonly used in West Usambara highlands. It should also be remembered that the effects of soil erosion and hence of soil conservation require a long time to be felt and realized – much longer than the timespan of this research; therefore, in a few cases, secondary data from other sources were used in this study.

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Chapter 2

SOCIAL AND ECONOMIC FACTORS FOR ADOPTION OF SOIL AND WATER CONSERVATION IN WEST USAMBARA HIGHLANDS, TANZANIA

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Social and economic factors for adoption of soil and water conservation in west Usambara highlands, Tanzania

Abstract

Accelerated soil erosion is one of the major constraints to agricultural production in many parts of Tanzania highlands. Although several soil and water conservation technologies have been developed and promoted, the adoption of many recommended measures is minimal and soil erosion continues to be a problem. This research was conducted in order to determine the social and economic factors that influence adoption of soil and water conservation (SWC) measures in the West Usambara highlands, Tanzania. For this research a household survey, group discussions and transect walks were undertaken. A total of 104 households were interviewed and several fields were visited during the transect walks. Data was analysed with the use of cross-tabulation, cluster analysis, factor analysis and chi-squared methods. The results obtained indicate that involvement in off-farm activities, insecure land tenure, location of fields and a lack of short-term benefits from SWC are among the major factors that negatively influence adoption of soil and water conservation measures. Membership in farmer groups, level of education, contacts with extension agents and SWC programs were found to be positively influencing the adoption of SWC measures. Recommendations to facilitate adoption of different soil and water conservation measures include: integration of social and economic factors into SWC plans, the creation of more awareness among farmers on soil erosion effects and long term benefits of SWC, the development of flexible soil and water conservation measures to cater for different farm patterns and a participatory approach to soil and water conservation at catchment level rather than at individual farmers' fields.

Key words: *Social and economic factors; Adoption; Soil and Water Conservation; Highlands; Tanzania*

Introduction

Background

Accelerated soil erosion poses a great threat to sustainable agricultural production in Tanzania. The West Usambara highlands are among the areas mostly affected by soil erosion in Tanzania. In these areas soil erosion leads to an annual loss of fertile topsoil up to 100 tha^{-1} and this greatly affects crop yields (Kaswamila and Tenge, 1998; Lyamchai et al, 1998; Pfeiffer, 1990; Shelukindo and Kilasi, 1993).

Several soil and water conservation programs have been implemented in West Usambara highlands to address soil erosion problems. Among these are the Mlalo basin rehabilitation scheme, Usambara scheme, the Soil Erosion and Agroforestry Program (SECAP), the Traditional Irrigation Program (TIP) and the African Highland Initiative (AHI) (Liversage, 1944; Stroud, 2000; Johansson, 2001). Over the years, these schemes have promoted various soil and water conservation measures, and in particular macro-contourlines, grass strips, terraces, ridges and later on kingamaji[1] and fanya juu[2]. However, the approaches to address this problem have been changing with time. Land degradation on West Usambara highlands started to receive attention between 1930s and 1945 during the colonial rule of Germans who were interested in forest products (Johansson, 2001). During this period population pressure was considered as the root cause of soil erosion.

Recommended measures included construction of bench terraces, tied ridges, enforced destocking, afforestation, prohibiting cultivation on steep slopes and resettlement of local people to lowland areas. Forest reserves were demarcated and local people prohibited from farming and taking fire-wood as they were used to do. These measures were implemented by force and made local farmers to hate the whole idea of soil conservation (Conte, 1999, Johansson, 2001).

The silent resistance of farmers to soil and water conservation increased the strength of the political struggle for independence and leaders promised to end soil conservation when independence was won. After independence of Tanzania (then Tanganyika) in 1961, land degradation continued. The government attempted to mitigate the land pressure in the West Usambara highlands by giving out land in forest reserves such as Shume and Magamba forest to landless people. Farmers were advised to grow different type of crops in rotation. However, there was unfair distribution of the newly opened forestland, farmers ignored crop rotation and expanded their fields to the forest area not allocated for expansion (Johansson, 2001).

In 1980s the government realized again the danger of soil degradation and several governmental, non-governmental (NGO) and International donor programs were started to address soil erosion problems. There was no forceful implementation of soil and water conservation anymore, but these projects would still follow a top down approach. SECAP, TIP and AHI were examples of such projects.

SECAP started in 1981 with financial support from the German foundation (GTZ). They developed and advocated a combination of biological measures called macro-contourlines in a form of improved grass strips, comprising different plant components, agroforesty trees, grass, creeping legumes and fodder shrubs (Johanson, 2001). However, farmers were sceptical, as, for instance after seven years of SECAP in Ubiri only 30 km of contour lines were established (Ulli, 1989). When farmers' performance did not meet the project expectation, SECAP changed the approach to soil conservation and adopted what is called catchment approach. In this approach soil erosion problem was addressed in a participatory manner at a focal area known as a catchment regardless of an individual farm boundaries.

In 1989 the TIP project supported by the Dutch Organization SNV started in the West Usambara Highlands. TIP approached soil and water conservation by attaching it to an irrigation package. Prior to being granted support for investment in irrigation, farmers needed to conserve their fields through afforestation and terracing. Successes were observed in areas where there was growing dependency on irrigation and farmers' awareness of the need for soil and water conservation. In other areas farmers were still not willing to participate and soil erosion continued.

[1] **Kingamaji** (Cut-off drains) are hillside ditches on the upper part of the field made to collect and safely evacuate the run off from outside the field. They are bigger than fanya juu and the excavated soil is thrown on the lower part.
[2] **Fanya juu** are hillside ditches within the field at specified intervals made by throwing the excavated soils on the upper part of the ditch. They reduce the speed of the runoff and trap eroded soil. Eventually the trapped soil forms a terrace.

AHI started in 1998 and addressed SWC in an integrated approach by combining soil conservation with other farming components such as improved crop varieties, dairy cattle, marketing, credit facilities and input stores (Stroud, 2000). The majority of farmers in the intervention areas adopted improved crop varieties such as banana, tomatoes and other vegetable crops. However, adoption of soil and water conservation was still not encouraging.

The limited success in all these efforts necessitates the investigation of the social and economic factors that influence farmers' willingness to invest in soil and water conservation activities. Experience from several SWC projects indicates that the problem of low adoption is often not due to the technology *per se*, but rather to the incompatibility of this technology with the prevalent social economic farming conditions (Jones and Tengberg, 2000; Kaswamila, 1995; Lucila *et al*., 1999; Samantha, 1996; Semgalawe, 1998).

Objectives

The major objective of this research is to investigate the social and economic factors that influence the adoption of soil and water conservation measures in the West Usambara highlands. Specific objectives are (i) To identify the type of households that reside and farm in the research area; (ii) To identify different methods of soil and water conservation used by farmers in the research area and (iii) To identify which socio-economic factors have a major influence on the adoption of these soil and water conservation measures by the various categories of farm households in the research area.

Information obtained from this research will be used by policy makers, the community in the watershed, individual farmers, researchers and extension staff to enhance adoption of different SWC in the West Usambara highlands and other areas with similar conditions in East Africa. Adoption of SWC measures will reduce soil erosion and increase land productivity and income to the farmers in the region.

Research area and farming systems

The research area

This research was conducted in Kwalei catchment ($4^0$48'S, $38^0$26'E) in the humid warm agro-ecological zone of the West Usambara highlands, Lushoto, Tanzania (Figure 1).

The area is representative of soil degradation zones in highland areas with respect to soil morphology, landscape, ethnic groups and socio-economic conditions. The total area of the catchment is 5 km^2 and it is situated at an altitude ranging from 800 to 1700 masl.

It has steep slopes of up to sixty percent and medium to high mountains with narrow valley bottoms (Meliyo et al., 2002). These variations in topography and aspects have created several microclimates and soil complexes (Pfeiffer, 1990; Conte, 1996). The catchment has a bimodal rainfall pattern with an annual amount of rainfall ranging from 1200 to 1700 mm (Pfeiffer, 1990). The long rainy season is from March to May and the short rainy season from September to November. The average daily temperature ranges from 18^0C to 23^0C with a maximum in March and a minimum in July (Wickama and Mowo, 2001). Major soil types according to FAO classification system are Humic Acrisols, Haplic Lixisols, Haplic Acrisols, Eutric Fluvisols and Umbric Gleysols (Meliyo et al., 2002; FAO, 1988). Kwalei catchment has a total of 516 households settled in twelve sub-villages. The estimated population in 2004 was 4120 people with an average annual growth rate of 2.8 per cent.

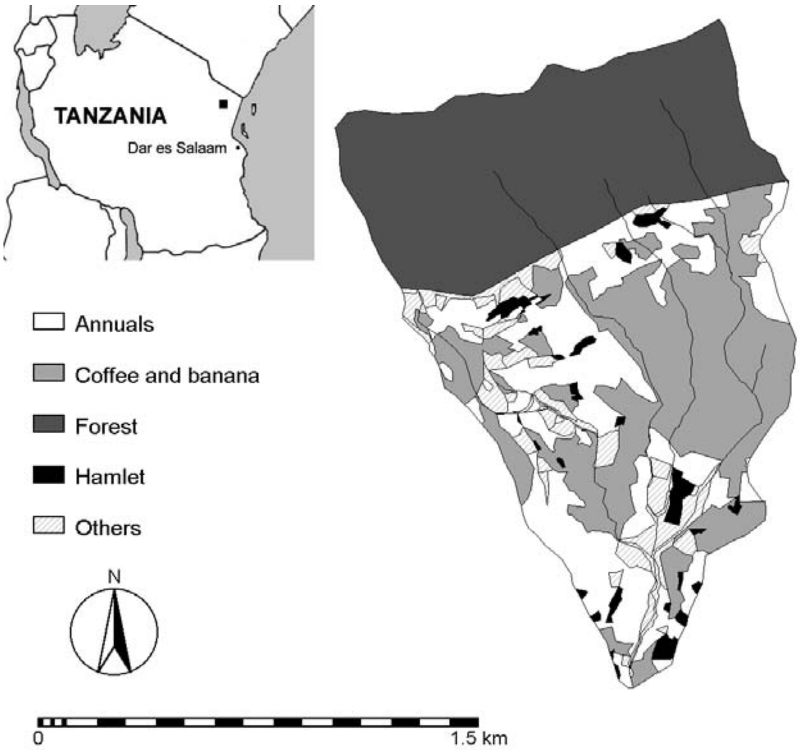

Figure 1. *Land use of Kwalei catchment in West Usambara Highlands, Tanzania*

Farming systems

The research area is characterised by a mixed-farming system, whereby farmers are involved in rain-fed agriculture, traditional irrigation in valley bottoms, livestock keeping and off-farm activities. Among these activities, rain fed agriculture is the most important, followed by irrigated agriculture, livestock keeping and off farm activities.

Major cash crops are tea, coffee and vegetables while banana, maize and beans are major food crops. Major cropping systems are coffee- banana intercrop with different trees species, maize-bean intercrop, tea as mono-crop and patches of sweet potatoes, tomatoes, sugar cane or cassava.

Cash crops are allocated to sixty per cent of the arable land. Land allocation to annual crops varies with season depending on economic importance and food preference (Lyamchai et al., 1998). On average a household has 1.4 ha for rain- fed agriculture. Soil erosion is one of the major constraints to agricultural production in the area such that more than one third of the catchment area is exposed to high and very high erosion risk (Meliyo et al., 2002, Vigiak et al., 2003). Survey results indicated that the most erosion prone fields are those of maize followed by beans.

Different types of land tenure systems exist in the study area, they include inheritance, purchase, borrowing, renting and public land (Lyamchai et al., 1998). A majority of households own land under the inheritance system whereby the land belongs to a certain family and is passed from one generation to another by the head of the household.

Research methodology

Data collection

Field research on the adoption of soil and water conservation was carried out in three main stages and involved both formal and informal survey methods (Chambers, 1992; Upton and Dixon, 1994; Valk and de Graaff, 1995; de Graaff, 1996). The first stage involved discussions with key informants and groups of farmers with the aim to obtain information and views about SWC and adoption from all farmers in the catchment. The second stage consisted of a formal household survey using pre-designed survey forms. This survey was held to collect specific and quantitative information from the representative farmers. Extension staff were also interviewed at this stage to obtain technical information. The third stage concerned transect walks across the catchment to obtain physical information and verify the information collected during the formal and informal surveys. Secondary data from scientific reports, maps and statistical abstracts were also used as additional sources of information.

The type of data collected at all three stages concerned: (i) farming system variables; (ii) household characteristics; (iii) farm household resource availability and resource use; (iv) external and institutional factors, including availability of extension agents, involvement in soil and water conservation programs and remittances from outside; (v) SWC options and farmers' reasons for preferences of different SWC.

Sampling procedure

For the household survey two-stage cluster sampling was applied: first sub-villages were selected and subsequently farm households were selected within these sub-villages. The twelve sub-villages in the catchment were divided into three groups, according to their location in the catchment: representing respectively lower (1200-1400 masl), middle (1400-1600 masl) and upper (above 1600 masl) altitude positions. Areas below 1200 masl concern valley bottoms that are not occupied by households. Seven of these twelve sub-villages were selected for the household survey. This stratification by location was undertaken, since it seemed likely that households in these locations would be affected in a different way by soil erosion, with its on-site and off-site effects.

The sampling frame at the second stage consisted of lists of heads of households obtained from the leaders of the sub-villages. These lists were further stratified according to the high-, middle- and low-income groups as established during an earlier participatory rural appraisal (Lyamchai et al., 1998). This stratification was done, because of the influence of resource endowment on land management and adoption of SWC measures. From the stratified sampling frame, systematic sampling was subsequently undertaken in such a way that a representative sample of male and female headed households were included in the sample (Table 1). In this way, a sample of 104 farmers was obtained, that was representative with regard to some characteristics that were hypothesized to affect adoption of SWC measures.

Table 1. *Sample characteristics*

Position on slope:	Sub-village	Gender head of household			Income group		
		Male	Female	Total	High	Medium	Low
Upper	Kwetongo	17	7	24	1	19	4
	Kingwele	10	2	12	1	8	3
	Ugange	15	1	16	2	12	2
Middle	Kweboma	12	5	17	0	15	2
	Kamajia	9	3	12	0	9	3
Lower	Kibaoni	7	4	11	0	10	1
	Shule	11	1	12	3	5	4
Total		81	23	104	7	78	19

Source: Field data 2002.

Data analysis

Data were analysed in order to answer the following research questions: (i) what are the type of household that reside in Kwalei; (ii) what are the major farming systems in the study area and how do they influence adoption of SWC measures; (iii) what SWC measures do farmers use in the research area; (iv) what are the farmers' criteria in selecting SWC measures for implementation? and (v) what are the relationships between social and economic characteristics and the adoption of SWC measures?

Farm household types and farming systems

Farm household types were distinguished on the basis of household characteristics, such as age, sex, education, marital status and family composition and also on the basis of resource availability, such as farm size, land tenure, possession of livestock, farm income, labour availability and involvement in off-farm activities. Farmers were asked to group the households in the catchment and mention criteria they used.

Cluster analysis was then used to group farmers and examine the conditions which can make them interested to implement SWC measures (Norusis, 1990). Farming- system analysis involved the identification and ranking of major crops, land uses, soil types, erosion status and climatic features. Crops were ranked according to the number of farmers who cultivate them.

Soil and water conservation measures and criteria for selection

Farmers were asked to mention different SWC measures they use in the area and the criteria that they use to select appropriate measures. SWC measures were then evaluated by their score on farmers' criteria on a scale of 1 (for bad) up to 4 (for very good).

SWC options with the highest scores were considered as the most preferred options based on farmers' criteria. Relative importance of each criterion was obtained by pair- wise ranking and the results expressed as the weight, which is the ratio of the total scores for individual criteria to the overall scores for all criteria (Belton and Reeves, 2002). Adoption of soil and water conservation measures was analysed in terms of the proportion of farmers undertaking the measures and in terms of the area covered.

Factors for adoption of soil and water conservation

Households with any of their fields conserved were identified and grouped as adopters and those with none of their fields conserved were identified and grouped as non-adopters. Cross tabulation (Norusis, 1990) was used to compare the household characteristics, location, resources endowment and external institutional factors between the adopters and non-adopters.

Factors not directly observable, but that might influence adoption of soil and water conservation measures, were analysed by the factor analysis method, as described in detail by Norusis (1990). However, the results from factor analysis did not differ from those of cluster and cross tabulation. They have been omitted in further analysis. The statistical significance of the identified adoption factors was evaluated by chi-squared method. This method compares the extent of differences and similarity between groups using the chi-squared (X^2) as the test statistics (Devore and Peak, 1993). Correlation between adoption factors was investigated by means of cross tabulation and the Pearson correlation coefficient (Devore and Peak, 1993; Norusis, 1990).

Household types and farming systems in the research area.

Household characteristics

The type of household that reside and farm in Kwalei catchment are indicated in Table 2. Based on household characteristics, resource availability and location, farm household categories can be distinguished in several ways, as shown in this section.

Male-headed household

Results indicate that 77% of the heads of households are married men. This group includes the most influential people and decision makers at the village and household levels.
While it is important to consider this influential group, care needs to be taken during planning of SWC so that other groups are not marginalized.

Female-headed household

Survey results indicate that 23% of the household heads are women. These women heading the household are either widowed or divorced. Villages in the upper-slope location have relatively many women-headed households. This may have negative effects on the adoption of soil and water conservation measures because female-headed households have limited access to information on SWC and to land and other resources, due to traditional social barriers. Women are also more involved in regular household activities than men (Lyamchai et al., 1998).

Table 2. *Type of households that reside and farm in Kwalei catchment*

Household characteristics	Description	Location: Upper	Middle	Lower	Average
Sex (%)	Male	73	81	78	77
	Female	27	19	22	23
	Sambaa	73	72	91	79
	Mbugu	13	10	0	8
	Taita	6	10	0	5
	Others	8	8	9	8
	L/primary	31	27	44	34
Education (%)	U/primary	29	47	31	35
	Secondary	0	6	13	6
	None	40	20	13	25
	Young	28	52	9	30
Age group (%)	Middle	16	22	30	23
	Old	26	19	35	26
	Very old	30	7	26	21
	Single	0	0	4	2
Marital status (%)	Married	83	83	78	81
	Divorced	6	0	4	3
	Widow	11	17	14	14

Source: Field data 2002.

Tribe

There are three major tribes residing in Kwalei: Sambaa comprising 79%; Mbugu 8% and Taita 5%. Traditionally the Mbugu people were livestock keepers and lived in isolated locations where they had enough land for grazing their animals. This might negatively influence the adoption of SWC as they depend more on livestock than on crops. SWC measures may also conflict with their interests of allowing free grazing to their animals. Survey results indicate that the majority of Mbugu people live on the upper slopes where they can graze their animals freely. SWC measures that provide fodder for livestock such as grass strips may attract this group to soil and water conservation.

Education level groups

Four education level groups can be distinguished in the catchment. Lower primary (1-4 years in school, upper primary (5-8 years in school), secondary (8-12 years in school) and non-formal education (less than 1 year in school). About 69% of the households have primary school education. Only 6% have secondary school education and the rest is without any formal education. Sub-villages on the upper-slopes have relatively many households without any formal education. Educated households, expected to understand soil erosion problems, have more access to information related to SWC and hence can more easily adopt different SWC measures.

Age groups

Four sub-groups were identified based on age: young (18-19 yrs), middle (36-45yrs), old (46-60yrs) and very old farmers (>60 yrs). About half of the farmers in the mid-slope area are between 18-35 years. This is the youngest generation involved in agriculture, with a longer planning horizon, more understanding of soil erosion problems, and thus more interested in soil conservation. Sub-villages on upper slopes have a higher proportion of farmers aged over 60 years. This may imply labour shortage for implementing SWC measures. Also, old farmers tend to be conservative, sticking to their traditional way of farming.

Farming systems and Resource use

Rainfed agriculture farmers

Over eighty percent of the households in Kwalei fall in this group (Table 3). Twenty two percent of farmers in this group are female-headed households.

The group grows tea and coffee as the main cash crops while banana, maize and beans are major food crops. Generally, men control cash crops while women except for female-headed households control food crops. This group could be stimulated to participate in soil conservation by ensuring availability of markets, good prices and SWC measures that improve crop yields.

Table 3. *Major economic activities and involvement of farmers in Kwalei*

Activity	Position on slope			Average	Gender	
	Upper	Middle	Lower		Female	Male
Rain-fed agriculture (%)	88	80	81	83	22	78
Traditional irrigation (%)	49	60	50	53	18	82
Livestock keeping (%)	59	25	23	36	15	85
Off-farm activities (%)	14	24	39	26	16	84

Source: Field data 2002. Percentages do not add up to100 because the same farmers are involved in several activities.

Irrigated agriculture farmers

During the dry season over fifty percent of farmers grow horticultural crops (tomato, cabbage, carrot, etc.) in the valley bottoms where they are irrigated by traditional methods. These valley bottoms are known as <u>kitiv</u>*o (*singularl*y)* or <u>vitivo</u> (plural).

In <u>kitivo</u> this group grows horticultural crops up to three times per year. Crops from <u>kitivo</u> have reliable markets and good prices such that the return to labour is higher than from rain-fed agriculture. According to Johansson (2001) the average return per ha of <u>kitivo</u> in West Usambara highlands is three times the return from rain- fed agriculture. This may have negative effects on eroded upland fields with low value crops like maize and beans. Attaching an irrigation component to the SWC measures can be an incentive for this group to participate.

Livestock keepers

About thirty-six per cent of households in Kwalei are involved in livestock keeping. Important types of livestock are cattle, goats and sheep. The main purposes for keeping livestock are meet, milk, manure and cash income. Table 3 indicates that only fifteen percent of livestock farmers are female-headed households.

Farmers who live on upper slope position are more involved in livestock keeping than others. This is due to the proximity to the grazing area near the forest. However, the average number of cattle per household has dropped from 10 in 1960 to 2-3 in 2000 (Lyamchai et al., 1998). This is due to the increasing shortage of open grazing area. This group can be stimulated to participate in soil and water conservation by considering SWC measures that provide fodder, such as grass strips or multi-purpose trees.

Households with off-farm activities

About twenty-six percent of farmers are involved in off-farm activities, including business (mini-shops, mini-restaurants, milling machine, etc) and technical jobs (carpentry, masonry, tailoring, blacksmith, shoe making and radio repair). Other activities include sand mining, stone crushing for construction and employment in different institutions (religious, estates, government, etc). Offering their labour and taking part-time jobs in the neighbouring Herkulu Tea Estate and Sakarani Mission are also common in the area. Women head only sixteen percent of households with off-farm activities. This indicates that female-headed households have relatively less economic options. Off farm activities may have a negative effect on adoption by reducing labour availability for SWC. On the other hand, off farm activities can be a source of income to invest in farming and SWC. Farmers who live in the lower and mid-slopes areas are more involved in off-farm activities than those in the upper-slopes. Possible reasons are the proximity to the road, ensuring transport and market access. Age is also a factor as the majority of households who live in the lower and mid-slope areas are young farmers and they own small fields from the inheritance system.

Income level groups

Three income level groups were identified based on farmers' criteria. They included households with high, middle and low incomes. Farmers' criteria for identifying these groups included size of the fields, type of crops they grow, level of education, ownership of cattle and labour availability (Lyamchai et al., 1998). However, discussion with farmers revealed that not all farmers in the high-income groups have applied conservation measures and manage their fields well. Participation of these income groups in SWC measures will either depend on their sources of income or what SWC can offer to facilitate their move from lower to a higher level of income.

Soil and water conservation measures

Important soil and water conservation measures used in Kwalei are, in order of importance: vegetative strips; bench terraces; fanya juu which are hillside ditches made by throwing excavated soils on upper part of the ditch; infiltration ditches; and cut-off drains. A total of 163 households had implemented these measures during the time of the study. The proportion of farmers for each measure and the extent of coverage are indicated in Table 4. Other measures include traditional agro-forestry plantations, trash lines and ridges. Important criteria for preference and evaluation of different SWC by farmers are indicated in Table 5. Minimization of soil loss, water loss and increase yields ranked high. These results indicate that the SWC approach should be of multi-purpose nature to cater for different farmers' objectives. A catchment approach in SWC provides the opportunity for considerations of all the different farmers' objectives (Kizughuto and Shelukindo, 2002, Thomas et al., 1997).

Table 4. *Implemented SWC measures in Kwalei*

Measure	Farmers (%)	Coverage	
		(m)	(ha)
Vegetative strips	55	12 375	4.6
Bench terrace	26	9 645	3.8
Fanya juu	15	6 958	2.8
Infiltration ditch	4	200	Na
Cut-off –drains	2	300	Na

Source : Field data 2002.

Na: not available.

Table 5. *Farmers' criteria for evaluating SWC measures in Kwalei*

Criteria	Objective	Weight	Rank
Soil loss	Minimize	0.16	1
Water loss	Minimize	0.13	2
Fertility	Maximize	0.13	2
Yield	Maximize	0.12	4
Fodder	Maximize	0.10	5
Irrigation	Maximize	0.09	6
Labour input	Minimize	0.07	7
Ease of tillage	Maximize	0.06	8
Simplicity	Maximize	0.06	8
Time of implementation	Minimize	0.04	10
Material input	Minimize	0.03	11
Maintenance needs	Minimize	0.01	12

Source: Field data 2002.

Factors for adoption of soil and water conservation measures

Household variables

(i) Tribe

Mbugu people have the lowest number of adopters compared to the other major tribes (Table 6). This is because Mbugu people depend more on livestock than crops. SWC measures also conflict with their interests in the free grazing of their animals. SWC measures with grass strips that provide fodder to livestock is the best option for this tribe. However, because of the small sample the statistical analysis does not give sufficient evidence that the tribe has any influence on adoption of SWC measures.

(ii) Gender of the household head

Statistically significant differences (p = 0.1) are found in adoption rates between male and female-headed households (Table 4). Female-headed households have adopted more often than male-headed households. An explanation for this observation is the fact that most fields affected by erosion in the area have been planted with annual food crops that are mainly cultivated by women. At present, women also have limited access to and use of alternative resources (Table 3). This suggests that if women were to be given an equal access to resources and to information on SWC, they would make a better contribution to erosion control than men. However, the large majority of households (seventy- seven per cent) are headed by men, and decision-making often rests with them.

(iii) Age

Both the youngest and the eldest households showed a low adoption rate of the recommended soil and water conservation measures (Table 6). This was not expected, especially not of the younger farmers, who should have a longer planning horizon and hence be more eager to investment in SWC. This low adoption rate among young farmers is due to their small farm size, resulting from the inheritance system, and also to their involvement in off-farm activities. Small farm sizes should promote a greater push to intensify the land they have, leading to more adoption of SWC. It is opposite in this case because of the opportunity costs of labour between SWC and off-farm activities. An explanation for the low adoption by old farmers is their labour shortage and the fact that they stick to their traditional way of farming.

These results are different from the findings by Pali et al., (2002). They found elder farmers in Tororo, Uganda to be the early adopters of SWC technologies, due to their wealth and social status in the community, which enable them to hire labourers for SWC activities.

Similar results were observed in Chuka, Kenya where female-headed households showed a high probability of adopting fertility improvement options (Kangai et al., 2002).

Table 6. *Household characteristics of adopters and non-adopters of SWC in Kwalei*

Variable	Description	Non-Adopters n=60	Adopters n=44	Chi-squared	Significant level
HH-Sex	Gender of the head of household			3	*
	% Male	62	38		
	% Female	43	57		
TRIBE	Ethnic group				Ns
	%Sambaa	57	43		
	% Mbugu	70	30		
	% Others	50	50		
SLOPE	Place of residence in catchment				Ns
	% Lower	57	43		
	% Middle	61	39		
	% Upper	57	43		
EDUC	Education (average school years)			20.2	***
	1<1 year (%)	67	23		
	1-4 years (%)	45	55		
	5-8 years (%)	64	36		
	8-12 years (%)	40	60		
AGE	Average age of head of household (years)			6.8	*
	18-35 (%)	69	31		
	36-45 (%)	39	61		
	46-60 (%)	50	50		
	>60 (%)	70	30		
EROP	Do not perceive erosion problem (%)	60	40	4.7	*

Source: Field data 2002.

Ns : not significant; * significant at 0.1; *** significant at 0.001.

(iv) Education level

Although the sample is small, the research shows that sixty percent of households with secondary-school education have adopted soil and water conservation measures compared to only twenty-three percent of households with no formal education (Table 6).

This is because educated households have a better understanding of soil erosion problems and have more access to information related to SWC. These results are similar to findings by Lucila et al. (1999) in the Philippine highlands and Pali et al. (2002) in eastern Uganda who both observed a positive influence of education on adoption of SWC. Unfortunately, like many parts of rural Tanzania, the majority of people with secondary school education do not stay in the rural areas because of poor social and economic services.

(v) Perception of erosion problem

Research results show statistically significant differences ($p = 0.1$) in adoption between household who perceive soil erosion as a problem and give it priority and those who do not perceive erosion as a priority problem on their fields (Table 6). The majority of farmers who have not adopted any SWC measure do not perceive soil erosion problems on their fields. This indicates that awareness about soil erosion problems influences the households with regard to the adoption of SWC measures.

The results are similar to the findings by Semgalawe (1998) who observed that perception and high ranking of erosion problems are among the factors that positively influence adoption of SWC in the northern mountains of Tanzania.

Farming and economic variables

(i) Field location

Results indicate that eighty-five percent of conserved fields are relatively close to the household home. This is due to the difficulties in transporting farm inputs, such as farmyard manure, to the distant fields.

Some farmers undertake SWC work as a part-time job during the evening, making it difficult to go to the fields that are located far from the home.

(ii) Farm and field size

On average a household has about 1.4 ha divided over 3-4 fields, which are scattered all over the catchment regardless of where the farmer resides (Table 7). These scattered fields contribute to the low adoption of SWC, as farmers have to decide where to invest first, depending on walking distance, labour requirements for fertilizer transport and production objectives. The size of fields is also too small to produce enough food and cash income for the family.

As a result ,the majority of farmers cultivate in the valley bottoms, where they can irrigate high-value crops for cash, with which they buy supplementary food. Other farmers cultivate fields outside the catchment. Some farmers are reluctant to implement SWC measures such as terraces and fanya juu out of fear that their small fields would be further reduced by these measures. Studies elsewhere by Shively (1997) and Fujisaka (1993), indicate that farmers regard small farm size as a barrier to invest in SWC. However, growing high-value crops and different types of multi-purpose trees or vegetative strips also provide other benefits such as fodder, firewood and manure, and these compensate for the losses (Stroud, 2000).

(iii) Relative location in the catchment

Results indicate that the position of the slope on which the household lives, does not influence the adoption of SWC measures (Table 6). This was not expected, as soil erosion does affect people in a different way at the respective positions on the slope. An explanation for this observation is that households in Kwalei catchment have several fields scattered all over the slope positions regardless of where the household lives.

This prevents farmers from taking the effects of erosion seriously, as what is lost from the upper-slope fields may be gained by the same farmer or family further down the slope.

Table 7. *Economic characteristics of adopters and non-adopters of SWC in Kwalei*

Variable	Description	Non-adopters n= 60	Adopters n= 44	Chi-squared	Significant level
RAAG	Involved in rain fed agriculture (%)	83	86		n.s
AFASZ	Average farm size (ha)	1.38	1.5		n.s
FIELDLOC	Conserved field closer to house (%)	0	85	20.8	***
LIVESTOCK	Average number of cattle (No)	3	2		n.s
LABOUR	Average full-time labour (No)	3	2		n.s
	Average part- time labour (No)	2	3		n.s
TENURE				3.9	*
	% Rented	100	0		
	% Borrowed	100	0		
	% Inherited	56	44		
	% Bought	55	45		
OFACT	Involved in off-farm activities (%)	66	34	27.9	***

Source: Field data 2002.

n.s: not significant, * significant at 0.1, *** significant at 0.001.

(iv) Rain-fed agriculture

Although maize and bean fields under rain-fed agriculture were identified as being those most prone to soil erosion, these crops are grown as a supplementary crop to bananas, which are the main food crop. During the long rains, maize is grown on fields within the catchment, while in the short-rain season over fifty per cent of households grow maize on fields outside the catchment. These factors discourage farmers from investing in soil conservation on maize and bean fields. Discussions with different groups of farmers revealed that the very long growing period for maize (March to August) and the sharp drop of coffee prices, from Tsh 1200-1400 kg $^{-1}$ in 1998 (Lyamchai et al., 1998) to only Tsh 350 kg $^{-1}$ in 2002, also discouraged them to implement SWC measures on these fields.

(v) Irrigated agriculture

Crops from kitivo have reliable markets and good prices. Consequently farmers invest most of their resources, including labour to this type of farming, and pay less attention to upland fields, particularly maize and bean fields. Samantha (1996) observed the same in Uluguru highlands, Tanzania where flat irrigable land suitable for vegetable production receives much more attention than steeply sloping maize fields. Kerr and Sanghai (1993) report the same findings in their research work in India. These observations suggest that SWC works should be planned and implemented such that they complement between investments with short- and long-term payoffs.

(vi) Livestock keeping

Generally there is not much livestock in the area. This has a negative effect on SWC measures, such as newly constructed terraces, since these traditionally require large amount of livestock manure. Farmers in the study area have been trained in applying alternative fertilizer options such as compost and green manure (Stroud, 2000). However, the majority of farmers nowadays apply the available manure on vitivo rather than on upland fields.

(vii) Labour availability

The major source of labour for farming activities in Kwalei is family labour, either as full- or part-time labour. Some farmers have been organized in small groups through which they share labour for different activities. Results show no significant difference in family labour size between adopters and non-adopters (Table 7). This suggests that decisions about labour allocation may be more important than the actual family labour size for implementing soil and water conservation measures. Another explanation is that adopters get additional labour to implement SWC from the labour sharing groups (Table 8). Adopters also receive and use remittances from their relatives outside the catchment to hire additional labour.

Table 8. *External factors for adoption of SWC measures in Kwalei*

Variable	Description	Non-adopters (%) n=60	Adopters (%) n= 44	Chi-squared	Significant level
INFOSWC	Received information on SWC	44	56	13.1	**
CONTEXT	Has contacts with extension	39	61	21.3	***
PARTSWC	Participated in SWC programs	41	59	26.5	***
LABSHARE	Membership in labour sharing group	18	82	20.4	***
MARKET	Perceive market problem	64	36	37.5	***
REMIT	Receive remittance from relatives	39	61	18.9	***

Source: Field data 2002.
** significant at 0.01, *** significant at 0.001.

(viii) Off-farm activities

Adoption results show sufficient evidence that involvement in off-farm activities negatively influences the adoption of SWC measures (Table 7). About sixty-six percent of households who are involved in off-farm activities have not conserved any of their fields. This is due to competition in labour between SWC and off-farm activities.

Lack of short-term benefits from SWC measures compared to off-farm activities also explain this observation. Similar results were observed by Hella (2002) in central Tanzania and Shiferaw and Holden (1998) in the Ethiopian highlands. Pali et al., (2002) obtained different results in Uganda, where farmers with off-farm activities were better adopters, implying that the off-farm income was used as source of cash to invest in SWC. These contrasting results indicate that where SWC is paying within the short term, farmers will use the income from off-farm activities to invest in SWC and vice versa.

(ix) Land tenure

Table 7 indicates that households with borrowed and rented land have not conserved any of their fields. This is due to the lack of security in land ownership under these systems. Studies from elsewhere (Shiferaw and Holden, 1998; Shively, 1997) have also shown that land security influences the adoption of SWC measures.

External factors

There is also a strong influence of external factors on the adoption of SWC conservation measures, as shown in Table 8. The majority of households who have adopted SWC measures have contacts with extension agents, SWC programs and/or are members of labour sharing groups. The research results also indicate that adopters receive remittances from their relatives and do not perceive the market opportunities as a big problem. These external contacts create a greater awareness among farmers of soil erosion and conservation. Farmer-to-farmer visits and study tours to other successful farmers can also increase the level of awareness and enhance adoption. Membership in labour-sharing groups also helps to alleviate labour shortage, which is often claimed as a limiting factor in the adoption of SWC measures. These results suggest that in order for the SWC programs to succeed there is a need for collective action and supporting policy and institutional set-up.

Correlation and interactions between factors of adoption

Results on the correlation and interaction between factors of adoption are indicated in Table 9. There is significant correlation and interaction between factors that influence adoption.

Important correlations are between the location of the household and the age, level of education, tribe, sex and involvement in off-farm activities of heads of households. The majority of households on the upper slopes are old households, with relatively low formal education, large numbers of cattle and less involvement in off-farm activities. The majority of female-headed households and the Mbugu tribe are also found on the upper slope position.

Other correlations are that between age and farm size, livestock, off-farm activities and external contacts. Old households have relatively large farms, which they own under the inheritance system. They are less involved in off-farm activities, have less external contacts and have relatively little labour available for their farm activities.

Table 9. *Correlation and interaction between factors of adoption in Kwalei catchment*

	Tribe	Sex	Age	Education	Farm size	Location
Education level		**	**			
Farm size		*	**			
Location		*	*	*		
Livestock number	**	*	**			*
Labour available		**	**		*	
Off-farm activities	**	**	**	*		**
Land tenure			*		*	
External contacts			*			*

Source: Field data 2002.

* correlation is significant at 0.05 (2-tailed).

** correlation is significant at the 0.01 (2-tailed).

There is also correlation between sex, education level, farm size and involvement in off-farm activities. Female-headed households have relatively lower education level, smaller farm sizes, are less involved in off farm activities and have few or no cattle.

Conclusions and recommendations

Conclusions

The adoption of SWC technologies is likely to increase with a higher level of education, a good perception of erosion problems and a better security in land tenure. On the other hand, fragmentation of fields over different locations, involvement in off-farm activities and a lack of short-term benefits from SWC negatively influence the adoption of SWC measures. Farmer groups, contacts with extension agents and SWC conservation programs are among the more effective means to disseminate soil and water conservation technologies.

Recommendations

Planners of SWC activities should identify social and economic factors with respect to SWC and integrate them into the plans. The most important are: household characteristics; resource availability; and external institutional factors.

SWC activities should be planned and implemented such that they complement between investments with short- and long-term pay offs. For instance, irrigation could be combined with implementation of SWC and short term, high-value crops on conserved fields.

SWC measures should not only be aimed at minimizing soil erosion but should also cover other household objectives, such as the improvement of soil fertility, yield increase and fodder for animals.

In order to enhance the adoption of SWC measures there is a need for institutional support of the extension services and SWC conservation programmes and an increased security in land tenure.

A greater awareness on soil erosion variables and long-term benefits of soil and water conservation measures needs to be created among farmers through training, demonstrations and exchange visits.

A catchment approach in soil and water conservation is needed so as to bring together farmers in different parts of the catchment who belong to different farming patterns.

Economic assessment of different SWC measures is needed to identify measures, that can be feasibly implemented by different farm patterns.

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Chapter 3

PHYSICAL EFFECTIVENESS AND FARMERS' PREFERENCES OF SOIL AND WATER CONSERVATION IN THE EAST AFRICAN HIGHLANDS

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Physical effectiveness and farmers' preferences of soil and water conservation in the East African highlands

Abstract

Soil erosion by water is a serious threat to sustainable agricultural production in the East African Highlands. Despite the severity of the soil erosion problem, there is not much quantitative information on the erosion effects and effectiveness of the recommended soil and water conservation (SWC) measures rendering SWC planning difficult. This study was conducted in Kwalei, Tanzania and Gikuuri, Kenya to assess the physical effectiveness of bench terraces, grass strips and fanya juu which are the most important SWC measures used in the East African Highlands. Fanya juu are hillside ditches made by throwing excavated soil on the upper part of the ditch. Gerlach troughs, trench ditches and runoff plots were used to assess the physical effectiveness while farmer's interviews and group discussions were used to obtain farmer's reasons for preferences of certain SWC measures. The results obtained show significant effects of SWC measures on soil loss, surface runoff, moisture retention and crop yields. Fanya juu is the most effective measure in reducing soil and water losses followed by bench terraces and grass strips. However, bench terraces retained more soil moisture and increased maize and bean yields more than fanya juu and grass strips. Apart from scientific criteria to evaluate SWC measures, farmers have other criteria which depend on their social and economic situations. Important farmers' criteria are provision of fodder, fertility improvement and low costs for implementation. To facilitate adoption of different SWC measures there is a need for integration of farmers' criteria into SWC plans. Further research work is recommended for identifying economically feasible SWC measures under different biophysical and socio-economic conditions.

Keywords: *Soil erosion; Soil and Water Conservation; Physical effectiveness; East African Highlands; Kenya; Tanzania.*

Introduction

Accelerated soil erosion is one of the major threats to sustainable agricultural production in many parts of the East African highlands (Gachene et al., 1997; Ovuka, 2000; Johansson, 2001). The West Usambara highlands in Tanzania and the Central highlands of Kenya are among the areas most affected by soil erosion (Pfeiffer, 1990; Conte, 1999; AHI, 2000; Van Roode, 2000; Angima et al., 2002). Soil erosion in these areas is causing loss of soil fertility, low crop yields, food deficiency and off-site effects such as siltation of waterways and damage to various structures.

Different Soil and Water Conservation (SWC) measures have been developed and promoted to minimise soil erosion in these areas (Jones, 1996; Thomas et al., 1997; SECAP, 1998; AHI, 2000). SWC measures that have been promoted in the area include; bench terraces, fanya juu, grass strips, cut off drains, infiltration ditches and micro-contour lines. These SWC measures are expected to reduce soil loss from water erosion, retain more moisture and nutrients the effects of

which increase crop yields. However, there is not much information to what extend these SWC measures achieve the expectations (physical effectiveness) so as to enable proper planning and convincing the farming community to invest in SWC.
The little information which is available has been delivered from very diverse methodological approaches and many different underlying assumptions, thus making it difficult for generalised application (Lal, 2001; Stroosnijder, 2003). This information often report the effects of soil erosion or the effectiveness of SWC measures in terms of soil loss (t ha^{-1}) or surface runoff (m^3 t ha^{-1}). The value of such information can be added by translating the loss due to soil erosion or the gain from SWC measures into crop yields or monetary terms which are of primary important to farmers.

Further more, the effects of soil erosion and hence SWC practices can vary according to the soils, crop and other management practices (Lal, 2001; Kaihura et al., 1999). Knowledge and preferences of farmers have also not been adequately considered in planning and implementation of SWC programs (Kruger et al., 1996; Tengberg and Stocking 1997; Conte, 1999; Ellis-Jones and Tengberg, 2000). Consequently, the adoption by farmers of the most recommended SWC measures is minimal and soil erosion continues to be a problem (Wenner, 1988; Mbaga-Semgalawe and Folmer, 2003; Tejwan, 2004; Tenge et al., 2004).

This research was conducted (1) to identify SWC measures that are used in two representative sites in the East African highlands, (2) to evaluate farmers' criteria in selecting SWC measures for implementation, and (3) to assess the effectiveness of the measures in reducing soil losses, and their impacts on crop yields.

Materials and methods

The study areas

This study was conducted in Kwalei ($4^0$48'S, $38^0$26'E) in the humid warm agro-ecological zone of the West Usambara highlands, Lushoto, Tanzania, and in Gikuuri (00^0, 26'S, 37^0,33'E) in Embu district entral highlands of Kenya (Figure 1).

The two sites are representative of highland areas of East Africa in terms of steep slopes, farming systems, and soil erosion problems. Kwalei site is located at an altitude ranging from 800 to 1700 meters, covering a total area of 500 ha. It is characterised by high mountains, ridges and narrow valley bottoms with steep slopes up to sixty percent (Meliyo et al., 2002). The area has a bimodal rainfall pattern with an average annual amount ranging of about 1100 mm. The first rainy season (long) is from March to May and the second rainy season (short) from September to November. The first rainy season is more reliable and contributes to about 70% of the total annual rainfall. But, due to differences in topography and slope aspects the annual rainfall amount in the zone which Kwalei represents vary from 800 to 1700 mm (Pfeiffer, 1990).
The major soil types according to FAO classification system are Humic Acrisols on hill summits, Haplic Lixisols and Haplic Acrisols on foot slopes and Eutric Fluvisols and Umbric Gleysols on valley bottoms (FAO, 1988; Meliyo et al., 2002).

The major economic activity in Kwalei is agriculture, on which over 80% of its population depends for their living (Lyamchai et al., 1998; Tenge et al., 2004). Tea, coffee and vegetables are major cash crops while banana, maize and beans are major food crops. Cattle, goat, sheep and chickens are the main livestock kept in Kwalei. The farm size per household range from 0.5 to 3 ha divided over 3 to 4 fields, which are scattered in different locations. More than one third of Kwalei area is exposed to high and very high erosion risks (Lyamchai et al., 1998; Meliyo et al., 2002, Vigiak et al., 2003). Survey results indicated that fields with maize and beans are the most prone to erosion

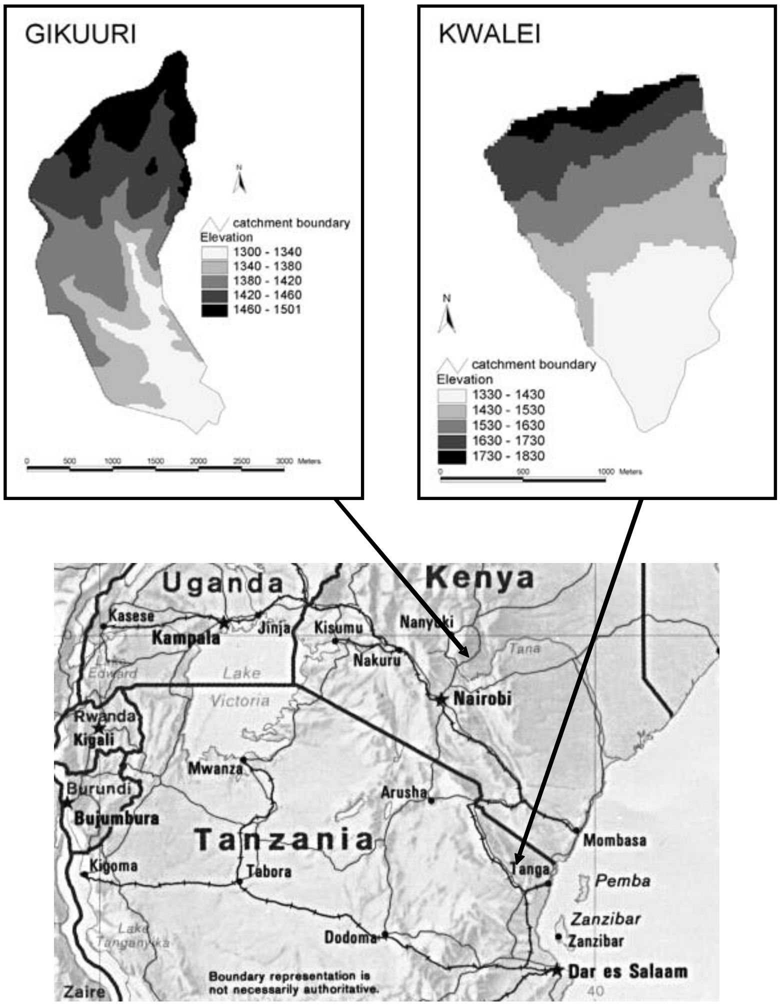

Figure 1. *Location of Kwalei and Gikuuri research sites*

Gikuuri site is situated at an altitude ranging from 1240 to 1573 metres and covers a total area of 500 ha. It is characterised by ridges and narrow valley bottoms with slopes up to 35%. The rainfall is distributed over the long-rains season from March to May, and the short-rains season from October to December. Annual rainfall ranges from 900 to 1200 mm with long- rains contributing about 54 % (Wanjogu, 2001). Soils on foot ridges are classified as Rhodic Nitisols, Haplic Acrisols, Chromic Cambisols and Chromic Luvisols (FAO, 1988; Wanjoku, 2001). Dystric Fluvisols and Gleysols are found on valley bottoms.

Agricultural is the main economic activity on which over 80% of the population depends for the living. Food crops are maize, sweet potatoes, round potatoes, bananas and beans. Cash crops include coffee, macadamia nuts, khat (mirraa) and various horticultural crops. Dairy cattle are mainly kept under zero grazing system where they are fed indoors. Farm sizes range from 1 to 2 ha per household. Soil erosion features like rills and gullies are widespread in the landscape (Okoba et al., 2004).

Data collection

Inventory of SWC

Inventory of SWC measures and farmers' priorities was done through different participatory methods which included group discussions, household surveys and field visits (Chambers, 1992; Defoer and Hilhorst, 1995; Graaff, 1996; Lyamchai et al., 1998). The aim was to identify the most important SWC options and understand farmers' preferences for certain SWC measures.

A household survey was conducted using pre-designed survey forms aimed to collect specific and quantitative information from representative farmers. A total of 104 farmers were interviewed in Kwalei and 161 farmers in Gikuuri. Extension staff in both areas were also interviewed to obtain technical information. Household surveys were followed by group discussions with key informants to get general information and views on SWC. Farmers' fields were visited to have the physical overview and verify the information collected during the household survey and group discussions. During the household surveys and group discussions, farmers were asked to mention different SWC measures they use on their fields and their criteria to select appropriate measures for implementation.

Farmers used the pairwise ranking method (Defoer and Hilhorst, 1995; Lyamchai et al., 1998; Stocking and Murnagham, 2001) to obtain the relative importance of the criteria they mentioned. Each SWC measure was assessed by giving a score on each criteria. The scores were on a scale ranging from 1 for poor to 4 for good. SWC options with the highest total score for all criteria was considered as the most preferred option (Belton and Reeves, 2002; Tenge et al, 2004).

Effectiveness of the SWC measures

The effectiveness of the SWC measures was assesed in farmers's fields under natural rainfall.The amount and duration of rainfall during the experimental period were measured with automatic rain gauges installed at four different locations within each site. Long term (1992-2001) rainfall data in Kwalei was obtained from the records at Kwalei primary school within the site. Long term data (1977-2001) for Gikuuri was obtained from KARI Embu, which is the nearest meteorological station at 17 km.

Assessment of the physical effectiveness was done in two stages. First stage involved comparing soil losses between adjacent fields with SWC measures and without measures using Gerlach troughs and trench ditch methods (Peden and Kakuru, 1993; Morgan, 1995; Mapashone, 2000). The aim was to quickly screen few promising measures for further scientific assessments. Gerlach troughs were locally made of closed metal sheet (0.5 m x 0.3 m x 0.2 m) fitted with a gutter (0.5 m x 0.15 m) at the front part. It had a removable lid on the top to prevent direct entry of rain and an opening on the lower part to allow flow of surface runoff to a collector. Total amount of surface runoff was measured after each erosive rainfall. The runoff was thoroughly mixed and a known volume of sub-samples taken to the laboratory where they were oven dried at $105^{o}C$ for 24 hours, weighed and sediment content determined per volume of surface runoff. A rough estimate of the contributing area to the collected surface runoff was made by dividing the area above the trough into grid intervals of 0.5 m using tape measure and strings. The number of grids within the contributing area were counted and used to estimate the area.

Trench ditches (0.3 m deep, 0.3 m wide) covering 2 m length were dug at the lower side of each field to be monitored. The ditch was lined with cloth materials to prevent scooping of trench walls during collection of eroded sediments. The amount of soil deposited in the ditch was removed after 3 to 5 erosive events, air-dried and weighed. Nine fields in Gikuuri and five fields in Kwalei were monitored during the long-rains of 2002. The fields in Gikuuri had bench terraces, fanya juu, grass strips and ridge and furrows. These were compared with adjacent fields with no SWC measures.

In case of Kwalei, the five fields had respectively fanya juu, grass strips, bench terraces (twice) and agro-forestry. They were also compared with five adjacent fields that had no SWC measure. Three SWC measures; grass strips (GS), bench terraces (BT) and fanya juu (FJ) were selected for detailed assessment of their effectiveness using runoff plots.

Measurements on runoff plots were only done in Kwalei during the short-rains of 2002 and long- rains of 2003. Runoff plots were laid out according to the complete randomised block design at four sites. The first site (I) was on a 32 % slope on a Haplic Acrisol, the second (II) at 35 % slope on Haplic Acrisol, the third (III) at 41 % slope on Haplic Lixisol and the fourth (IV) on 59 % slope on Humic Acrisol soil type. Treatments were the three SWC measures (GS, BT and FJ) and these were compared with the without SWC situation (Control). Runoff plots were enclosed by metal sheets to prevent surface run-on from outside. The lower ends of the sheets were attached to the troughs that diverted surface runoff to the collector at the lower end of each plot. Plot sizes ranged from 3.5 m by 16 m to 4 m by 17 m depending on the available field size from the farmers. Surface runoff was collected after each erosive rainfall, the total volume was measured and well-mixed sub-samples taken to the laboratory where they were oven dried for determination of suspended sediment content. Soil loss from each individual erosive event was obtained as the product of total surface runoff and the sediment concentration. Apart from surface runoff and soil loss, soil moisture content of the surface soil (0-20 cm) was measured using a time domain reflectrometry (TDR) moisture-meter method (Topp, 1980; Kutilek and Nielsen, 1994). Moisture content measurement was done on weekly basis during the growing seasons in short-rains 2002 and long-rains 2003. Maize (*Zea mays*) was grown during the long-rains of 2003 and bean *(Phaseolus vulgaris)* during the short- rains of 2002. Maize was planted at a recommended spacing of 0.3 m within rows and 0.75 m between rows. Manure was applied to each plot before planting at the recommended rate of 5 t ha^{-1} .

Nitrogen fertiliser in the form of urea was applied at the recommended rate of 100 kg ha^{-1} when plants were at knee height. Other agronomic and management practices were applied uniformly to all plots. Beans were planted at a spacing of 0.25 m within rows and 0.5 m between rows. No manure was used for the beans. Plant growth and yield were monitored in terms of height at early, middle and maturity stages, and grain yields at harvest. Dry grain weight was measured at 13% moisture content and the results converted to kg ha^{-1}.

Data Analysis

Both qualitative and quantitative statistical techniques were applied in data analysis. During field experiments, farmers were involved in assessment by pair wise ranking of the measures depending on crop performance and erosion indicators such as rills and broken SWC measures if they developed after rainstorms. Field data were processed and analysed with Microsoft Excel and SPSS computer programs (Norusis, 1990; Kachigan, 1991). Analysis of Variance (ANOVA) was performed to determine the effects of SWC measures on surface runoff, soil loss and moisture retention. In this analysis, F-value was used as the test statistic (Steel and Torrie, 1980; Devore and Peak, 1993). Least significant difference (LSD) at 5 percent probability was used to identify SWC measures with sufficient evidence of differences.

The effectiveness of the SWC measure was evaluated and expressed as an erosion reduction factor (E), which is the percentage of the reduction in soil loss or runoff loss to the loss from control plots/fields (Equation 1 & 2). In this form (E), it was possible to compare the results from different methods used to assess the effectiveness.

$$Es = \left(\frac{So - Sc}{So}\right) * 100 \qquad (1)$$

Where:
Es = Reduction factor for soil loss (%)
So = Soil loss from control plot/field (t ha^{-1})
Sc = Soil loss from conserved plot/field (t ha^{-1})

$$Er = \left(\frac{Ro - Rc}{Ro}\right) * 100 \qquad (2)$$

Where:
Er = Reduction factor for surface runoff (%)
Ro = Surface runoff from control plot/field (mm)
Rc = Surface runoff from conserved plot/field (mm)

Results and discussions

Farmers' criteria for selecting SWC measures

Important criteria for preference of different SWC measures by farmers are effectiveness in reducing soil and water losses, fertility improvement, increase in crop yields, low labour and material inputs and provision of fodder for livestock (Table 1).

These criteria used by farmers emphasise the importance that SWC measures should not only aim at reducing soil erosion but also increase productivity within time frame and resources endowment of the respective farmers. The observations partly explain the reasons for the low adoption of SWC technologies that have been developed without farmers' participation and focus on a single aspect of soil erosion. For instance, Wezel et al. (2002) in Vietnam observed that farmers did not adopt Tephrosia Candida because it could only be used as mulch and had no direct benefits as fodder. Similarly, Dejene et al. (1997) reported a low adoption of zero grazing to improve milk production and minimise soil erosion in Tanzania, because farmer's preference was in manure rather than in milk and soil loss reduction.

Table 1. *Farmers' criteria for selecting SWC measures in Kwalei and Gikuuri*

Criteria	Rank†	
	Kwalei	Gikuuri
Soil conservation	1	1
Fertility improvement	2	8
Water conservation	2	1
High yield	4	3
Fodder and fuel	5	6
Irrigation possibility	6	8
Low labour input	7	5
Simplify tillage	8	8
Time of implementing	9	8
Simplicity	10	4
Low material input	11	8
Minimum maintenance needs	12	7

† 1: High priority; 12: Least priority

Soil and water conservation options

The inventory and ranking of SWC measures using farmer's criteria, show that Kwalei farmers had nine options while Gikuuri farmers had eight options (Table 2).

According to the ranking by farmers bench terraces, fanya juu and grass strips are the most important SWC measures in both sites. Other SWC measures were ranked differently by farmers in the two sites. These differences in ranking were mainly due to the differences in soils, slope, and farming system. Brief definitions and farmers's views on of these SWC measures are given below.

Bench terraces consist of a series of level or nearly level platforms built along the contour line at suitable intervals. They are suitable for farms on steep slopes with deep soils, and for intensively cultivated fields. Bench terraces are recommended on slopes between 35 and 55 % (Shelukindo, 1995). According to farmers, in both sites; bench terraces are labour intensive, they reduce cultivable areas and may decrease crop yield in the initial stage unless there is high fertilisation. However, farmers, preferred bench terraces because of their effectiveness in erosion control, potential increase in yields and possibilty of irrigation on steep slopes once they are constructed.

Table 2. *Farmers' ranking of soil and water conservation options in Kwalei and Gikuuri*

SWC-measure	Farmers' ranking	
	Kwalei	Gikuuri
Bench terraces	1	1
Fanya juu	2	1
Grass strips	3	3
Agro forestry	3	**
Cover crops	**	4
Infiltration ditches	5	**
Cut-off drains	5	**
Fanya chini	**	8
Deep tillage	7	**
Trash lines	8	5
Ridge and furrow	9	7
Mulching	**	5

** Not applicable; 1: fulfil most of farmers' criteria; 10: fulfil very few of farmers' criteria

Fanya juu are hillside ditches made by throwing excavated soil on the upslope of the ditch. They are built along the contour lines at the appropriate intervals depending on the slope. These hillside ditches break long slopes into shorter segments and therefore intercept surface runoff. With time these fanya juu accumulate soil and build up to terraces (fanya juu terraces). Fanya juu are common at slope gradient between 12-35%. According to farmers, fanya juu are effective in reducing soil and water loss and they are less labour demanding compared to bench terraces. However, women farmers in Kwalei had a different view, meaning that fanya juu are more labour intensive due to the action of throwing the soil upslope.

Grass strips consist of different grass species planted in strips along the contour lines. The strips are spaced at suitable intervals to decrease surface runoff velocity and to retain eroded sediments. Grass strips are established on gentle slopes between 5–12%. Besides reducing soil erosion grass strips provide fodder for livestock and improve fertility if appropriate grass species are planted According to farmers in both sites, grass strips are cheap and simple to make, although there is an additional cost of maintenance and some grass species compete with crops for water and nutrients.

Agroforestry refers to land use practices where perennial trees are deliberately integrated with crops and animals on the same land management unit. Trees provide timber, fuel wood, fruits and some trees can provide fodder for livestock and improve soil fertility. If appropriate tree species are planted in macro contour-lines together with grasses in rows, this system act as SWC measure by reducing the speed of surface runoff and retaining the sediment carried by the surface runoff (Shelukindo, 1995). However, not all agroforesty systems and practices reduce soil erosion, and farmers in Gikuuri did not consider trees in their fields as agroforesty system for soil erosion control (Table 2).

Cover crops refer to the growing of crops that cover the soil for a large period of the rainy season. Cover crops prevent soil erosion by reducing the impacts of raindrops on the soil. Cover crops are less labour demanding, they improve fertility and some can be used as fodder.

Infiltration ditches (Vuna maji) are almost level channels built across slopes of 12% to 55%. They are meant to increase infiltration of water into the soil. They can also be used as an alternative for cut-off drains where there is no place for water discharge and as water harvesting structures to convey in and store water for irrigation. Some farmers prefer them as trap for sediment coming from upslope fields (AHI, 2000). Infiltration ditches are labour intensive and more suitable in areas with low rainfall where they can be used as a water harvesting structures.

Cut-off drains are open trenches with an embankment on the lower side. It acts as the first line of defence to protect the land below from surface runoff (Shelukindo, 1995). Cut-off drains are constructed on slopes of over 55%. According to farmers, cut-off drain protects a large area and is effective in removing large amounts of surface runoff. However, it is labour intensive and requires agreement among farmers as it affects several fields.

Fanya chini are hillside ditches made by throwing excavated soil on the lower side of the ditch. They prevent sediment losses below the ditch and act as water harvesting structures. Unlike fanya juu, they do not develop into fanya juu terraces. According to farmers, they are less labour demanding compared to fanya juu as it is easier to throw the excavated soil on lower part than on the upper part as it is done with the fanya juu.

Deep tillage refers to digging deep (25-30 cm) and converting the soil during land preparation and leaving large soil clods on the surface. This practice reduces soil erosion by increasing surface roughness and infiltration rate. According to farmers, deep tillage is less effective on steep slopes. Observations during field surveys showed that although this practice can reduce water erosion, it causes significantly downward soil movements (tillage erosion) on steep slopes.

Trashlines are surface runoff barriers made of crop residues which are arranged in strips along the contour lines. They function like grass strips in preventing sediment and water losses by erosion.They received low ranking by farmers in both Kwalei and Gikuuri because its application is limited by availability of sufficient crop residue materials which are also used to feed animals under zero grazing.

Ridge and furrows are small linear bunds constructed across the slope with furrows between them. They prevent soil erosion and retain moisture between these furrows. They are less labour intensive but have to be constructed each season and are less effective on steep slopes.

Mulching refers to the application of an artificially applied layer of plant residues on the surface of the soil. The plant residues used as mulch protect the soil from erosion, improve soil fertility, moisture retention capacity and organic matter content. In addition, mulching reduces the frequency of weeding. Availability of sufficient mulching materials and difficulty in transporting to upslope fields are the major limitation for its wide use.

The list of SWC options in the two sites cover a wide range of SWC measures that are applicable elsewhere. This minimizes the possibility that low adoption of SWC measures is due to a limitation in the SWC options.

Effectiveness of SWC measures

Rainfall

The total rainfall amount in Kwalei during the experiment period was 622 mm for the short-rains 2002 and 392 mm for the long-rains 2003. The short-rains received almost twice the long term average of 284 mm, while the long-rains were very dry compared to the long term averages of 725 mm. The total rainfall amount in Gikuuri was 576 mm in the short-rains of 2002 and 755 mm for the long-rains of year 2003. These rainfall amounts were closer to the long term averages of 562 mm for the short-rains and 708 mm for the long-rains.

Gerlach troughs and trench dithes

Results from Gerlach troughs in Kwalei show a clear reduction of soil loss by SWC measures (Table 3).

Table 3. *Effectiveness of SWC measures in reduction* of soil loss and surface runoff measured by Gerlach troughs in Kwalei, Tanzania in 2002-2003

Slope‡	SWC	Soil loss	Surface runoff	Effectiveness	
				Soil loss	Surface runoff
(Class)		(Mg ha^{-1})	(m3 ha^{-1})	(%)	(%)
Moderate	Control	4.8	1.14	0	0
	Agroforesty	0.1	0.12	98	89
	Fanya juu	0.1	0.06	99	95
Steep	Control	9.7	0.84	0	0
	Grass strips	0.4	0.24	96	71
Very steep	Control	12.8	2.34	0	0
	Bench terraces	0.2	0.13	98	94

‡ Moderate (13-25%), Steep (26-35%), Very steep (>55%)

However, the results indicate that all the SWC measures were equally effective in reduction of soil losses. This was not expected as these SWC measures differ in the design and mechanism on how they reduce soil erosion. This was due to the small size of the Gerlach troughs which measured losses only through their relative small width compared to the width of the field. Different in age, spacing and maintenance levels by farmers who owned fields with these SWC measures also have contributed to these observations. It should be noted that Gerlach troughs were only meant to quickly compare erosion status between conserved and non-conserved fields.

Therefore, these results should not be used on absolute terms for comparing the effectiveness of different SWC measures.

Results from trench ditches in Gikuuri, indicate clear differences in soil loss between control and fields with different SWC measures (Table 4).

The effectiveness of all SWC measures decreased with an increase in slope steepness. The low effectiveness of fanya juu and bench terraces at steep slopes is due to poor maintenance. Discussion with farmers revealed that these bench terraces were constructed because of the regulations that required bench terraces on fields with coffee. Due to the drop in coffee prices, farmers no longer maintain these bench terraces as they are no longer financial attractive. This observation provides a good example that soil erosion and conservation are influenced by both physical and socio economic situations.

Table 4. *Effectiveness of SWC measures in reduction of soil loss measured by trench ditches in Gikuuri, Embu, Kenya*

Slope‡ (Class)	SWC	Soil loss ($t\ ha^{-1}$)	Effectiveness (%)
Gentle	Control	4	0
	Bench terraces	1.5	61
	Fanya juu	0.8	80
	Grass strips	0.8	68
	Ridge& furrows	0.7	82
Very steep	Control	6.8	0
	Bench terraces	3.7	46
	Fanya juu	2.9	58

‡ Gentle (6-15%), Very steep (> 32%)

Runoff plots

Soil moisture

Results on soil moisture measurements show sufficient evidence of differences in moisture content between conserved and not conserved plots (Table 5).

Bench terraces retained more moisture than other SWC measures. This is because of their nearly level platforms that retained surface runoff and allowed much time for water to infiltrate into the soil. Fanya juu retained more moisture than bench terraces in year 2002 at site III (41% slope) because, construction of bench terraces at this site exposed subsoil which was shallow and stony.

The results support farmer's explanation that bench terraces may cause soil degradation by exposing subsoil with low fertility. Moisture levels were generally higher in year 2002 than in 2003, due to differences in rainfall amount between short-rains in 2002 and long-rains in 2003.

The ability of beans to cover the soil and prevent moisture loss also was the reason for this observation. These results are similar to the observations by Gardner and Gerard (2003) who observed the variability in terraces response due to vegetative cover and varying storms in the hills of Nepal. Vegetative cover effects of leguminous crops have also been reported in Northern Honduras (Bunch, 2004) where soil and water loss on 35% slope was significantly reduced by velvet bean (mucuna) which constantly covered the soil.

Table 5. *Effects of SWC measures in retention of soil moisture in the top soil in Kwalei*

Season	Slope†	Average volumetric moisture content			
		Control (%)	Grass strips (%)	Bench terraces (%)	Fanya juu (%)
Short-rains 2002	I	30.5 a‡	29.5 a	39.8 b	31.2 a
	II	29.0 a	30.2 a	34.8 b	29.3 a
	III	28.0 a	29.0 a	29.7 a	35.1 b
	IV	26.6 a	28.2 a	39.1 b	35.9 b
Long-rains 2003	I	25.4 a	26.8 a	33.4 b	27.1 a
	II	25.3 a	25.4 a	38.8 b	26.7 a
	III	27.1 a	28.0 a	32.1 a	28.8 a
	IV	24.8 a	23.9 a	32.7 b	25.6 a

† I Slope = 32%, II Slope = 35%, III Slope = 41%, IV Slope = 59%.

‡ Figures followed by the same letter in rows are not significant different at 5 percent probability.

Soil loss

Results from runoff plots show significant differences in soil loss between conserved and non-conserved plots (Table 6).

Table 6. *Effects of SWC measures on reduction of soil loss in Kwalei*

Season	Slope†	Soil loss			
		Control ($t\ ha^{-1}$)	Grass strips ($t\ ha^{-1}$)	Bench terraces ($t\ ha^{-1}$)	Fanya juu ($t\ ha^{-1}$)
Long rains 2003	I	9.5 a‡	5.9 b	3.1 bc	1.0 c
	II	9.0 a	4.1 b	2.1 bc	0.5 c
	III	17. 2 a	10.2 b	2.8 c	0.9 c
	IV	22.9 a	12.8 b	4.5 c	0.7 d
Short rains 2002	I	6.7 a	3.3 b	2.3 b	1.1 b
	II	7.5 a	4.8 ab	2.9 b	1.8 b
	III	10.4 a	5.6 b	2.6 c	2.1 c
	IV	13.9 a	11.1 a	4.2 b	2.8 b

† I Slope = 32%, II Slope = 35%, III Slope = 41%, IV Slope = 59%

‡ Figures followed by the same letter in rows are not significant different at 5 percent probability

Fanya juu is the most effective in reducing soil loss followed by bench terraces and grass strips. The results are similar to the findings by Van Roode (2000) who observed that fanya juu was most effective by reducing soil loss to 4% in Machakos, Kenya. Evaluation of the measures during the research showed that the losses from SWC measures were mainly from the risers especially at initial stages when they were not stabilised. Van Dijk (2002) also observed this phenomenon on the study of water and sediment dynamics in bench-terraced fields in Indonesia. Soil loss on fanya juu can be recovered by removing the sediment from the ditches and putting it back to the land, but it would have lost nutrients through leaching and there will be an additional cost of labour. The results show that more soil loss occurred in long rains of 2003 than in the short rains of 2002. This was due to the larger ability of beans to cover the soil and to protect it from erosion than maize, since maize has little cover especially in initial stages. Site IV lost more soil than all other sites in both short and long rains because of a very steep slope (59%). This is not surprising as it is well documented that slope steepness increases soil erosion (Lal, 2001).

The results are in agreement with farmers who classified the soils in site IV as highly eroded (Okoba et al., 2004). The soil losses observed in the control plots were much less than the annual averages of up to 100 (t ha) that has been commonly perceived to occur in the Usambara highlands (Pfeiffer, 1990; Kaswamila, 1995; Lyamchai, 1998). These data can not be strictly compared because they were obtained in a variety of ways and from different biophysical and land management situations. For example, Kaswamila (1995) estimated soil loss using microtopographic features and erosion pins which are likely to overestimate the erosion rates. However, these data give some idea of the threat and diversity of erosion rates present within the region. Low amount and poor distribution of rainfall during the research period could have contributed to these lower erosion rates. This could also indicate that soil degradation has passed certain threshhold levels. The fact that soil erosion has higher yield decline impacts on an intitially pristine soil than on an already badly eroded soil (Tengberg and Stocking 1997) imply that soil erosion is expected to be higher on deep and fertile soils than on shallow and degraded soils if other factors of erosion are constant.

Surface runoff

Results indicate that fanya juu was more effective in reducing surface runoff than other SWC measures (Table 7).

Table 7. *Effects of SWC measures on surface runoff generation measured by runoff plots in Kwalei*

Season	Slope†	Surface runoff			
		Control (mm)	Grass strips (mm)	Bench terraces (mm)	Fanya juu (mm)
	I	12.3 a‡	9.6 ab	5.7 bc	2.5 c
Long rains-2003	II	9.2 a	4.6 b	3.6 bc	1.8 c
	III	8.0 a	5.4 ab	3.1 b	2.2 b
	IV	14.8 a	11.6 ab	7.4 b	4.3 b
Short rains-2002	I	4.5 a	4.1 a	2.6 ab	2.1 b
	II	5.4 a	3.9 ab	3.4 b	1.6 c
	III	8.9 a	5.7 b	3.7 b	1.9 bc
	IV	6.2 a	5.5 a	3.8 b	2.5 b

† Slope categories: I = 32%, II = 35%, III = 41%, IV = 59%

‡ Figures followed by the same letter in rows are not significant different at 5 percent probability

Like soil loss, surface runoff was more generated in year 2003 than in 2002, despite the low rainfall during the long-rains in 2003. Site IV had overall higher runoff amount than other sites because of very steep slopes (59 %). These results are similar to observations by Van Roode (2002) in Machakos, Kenya where fanya juu was far most effective by reducing surface runoff by 80% and soil loss by 96%

Effectiveness (E)

Results on the effectiveness of SWC measures show similar trend to soil loss and surface runoff. Fanya juu is the most effective followed by bench terraces and grass strips (Table 8).

All the three SWC measures were more effective in reducing soil loss than surface runoff. This is because eroded sediments are deposited when they reach barriers like SWC measures, while surface runoff can filter through the barrier. This is similar to observations by Temple (1972) who reported that Napier grass strips reduced surface runoff by 15% and soil loss by 45%. Van Dijk (2002) in Java, Indonesia reported the reduction of surface runoff by 60% and soil loss by 70% by bench terraces. The results show no clear trend of effectiveness with the change in slope. The effectiveness increased with age of the SWC measure, being lower in year 2002 than in year 2003 for all measures. This is because of stabilization and growth of stabilizer grasses which increased with time. This is comparable to the observations by Angima et al. (2002) in Embu Kenya, who reported an effectiveness of 30% to 80% of grass strips depending on the age, specie and spacing. Renard et al. (1996) observed the effectiveness of 20% to 50% for terraces depending on the slope and the spacing.

Table 8. *Effectiveness of SWC measures in reduction of soil and water losses derived from runoff plots in Kwalei*

Season	Slope†	Effectiveness					
		Soil loss			Surface runoff		
		GS (%)	BT (%)	FJ (%)	GS (%)	BT (%)	FJ (%)
Long rains 2003	I	38	67	89	22	50	74
	II	54	77	94	45	57	79
	III	40	84	95	32	61	72
	IV	44	80	97	21	50	71
	Mean	44	77	94	30	55	74
Short rains 2002	I	51	66	84	10	42	54
	II	36	61	76	28	37	70
	III	46	75	80	30	53	77
	IV	20	70	80	12	40	60
	Mean	38	68	80	20	43	65

† Slope categories: I = 32%, II = 35%, III = 41%, IV =59%
GS: Grass strips; BT: Bench terraces; FJ: Fanya juu

The results from all the three measurement methods have indicated that the assessed SWC measures are effective in reduction of soil erosion if they are properly constructed and maintained. However, as indicated by farmers their preference on SWC does not depend on the effectiveness alone, there is a need for further analysis to assess the effectiveness and efficiency of these measures on other criteria.

Crop yield

Effects of soil erosion and SWC measures on crop growth and yield are difficult to quantify within a short period as they take longer time to materialize and they are accumulative. In addition there is an interaction with other factors such as rainfall, which vary with time and space. However, there is an indication on how SWC can be effective. The results from this study indicate a clear increase in maize yield in all plots with bench terraces (Table 9).

This is due to the effectiveness of bench terraces to retain soil moisture (Table 5). Maize yields from site III are not presented because there was a crop failure caused by other factors than erosion**.** Similarly, the yield of beans increased with SWC measure, being high in plots with bench terraces and fanya juu for all sites. Unlike maize, high erosion at site IV did not significantly affect beans. These results support the observations by other research that leguminous crops are less sensitive to impacts of erosion than cereals (Tengberg and Stocking, 1997). Although the yields obtained in plots with SWC measures are still lower than the potential yield of 4000 kg ha^{-1} for maize and 600 kg ha^{-1} for beans, they are far above the average yields from farmers fields. The reasons are extrapolation of plot data assuming uniform crop yields and differences in management levels between experiment and farmer situations.

Table 9. *Effects of SWC measures on maize and bean yield in runoff plots in Kwalei*

Crop	Slope†	Crop yield			
		Control (kg ha^{-1})	Grass strips (kg ha^{-1})	Bench terraces (kg ha^{-1})	Fanya juu (kg ha^{-1})
Maize	I	1990	2369	3123	2389
	II	1374	1959	3401	3100
	IV	1340	1250	1500	1360
Beans	I	159	200	403	421
	II	174	239	251	213
	III	125	127	133	130
	IV	248	221	306	336

† Slope categories: I = 32%, II = 35%, III = 41%, IV = 59%

Conclusions

The results from this research has shown that besides the frequently evaluated criteria for the effectiveness of SWC measures by researchers and scientistist, farmers have their own criteria depending on the social and economic situations. Important criteria for preference of certain SWC measures by farmers in the research area are effectiveness in reducing soil and water losses, soil fertility improvement, increase in crop yield, provision of fodder for livestock and low costs. However, there is no single SWC measure that can meet all the farmer's criteria, suggesting a need for combination of several SWC measures.

Assessment of the SWC measures using both farmer's and scientific criteria has revealed that important SWC measures in the study areas are bench terraces, fanya juu, grass strips, agroforestry, cover crops, infiltration ditches, cut-off drains and fanya chini. Among these SWC measures, fanya juu is the most physically effective in fanya chini followed by bench terraces and grass strips. However, Bench terraces are the most effective in moisture retention and in yield increase. This research have also indicated that there is big potential to increase crop yields by implementing SWC measures. The yield increase due to SWC measures is likely to be higher for maize than for beans.

The positive results on the physical effectiveness of the evaluated SWC measures, suggest that the low adoption of SWC measures is due to other criteria mentioned by farmers such as high costs, time of implementation and durability. This suggests that farmers are likely to implement SWC measures if their preferences are identified and considered in planning and implementation of SWC programs. In view of this, there is a need for further research to identify SWC measures, which are financially feasible under different farmer situations.

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Chapter 4

THE FINANCIAL EFFICIENCY OF MAJOR SOIL AND WATER CONSERVATION MEASURES IN WEST USAMBARA HIGHLANDS, TANZANIA

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The financial efficiency of major soil and water conservation measures in West Usambara highlands, Tanzania

Abstract

Soil and Water Conservation (SWC) measures are needed to control soil erosion and sustain agricultural production on steep slopes of West Usambara Mountains. However, the adoption by farmers of the recommended soil and water conservation measures has fallen short of expectation. It could well be that the reason for non-adoption is that the costs to invest in soil and water conservation are higher than the eventual benefits. This research assessed the costs and benefits of bench terraces, grass strips and *fanya juu* that are major SWC measures. Financial Cost Benefit Analysis (FCBA) was undertaken for farmers with low, moderate and high opportunity costs of labour at different slopes and soil types. The results show that labour is the major cost item in implementing SWC measures and is higher with bench terraces than with *fanya juu* and grass strips. The results also show that the costs of establishing the three SWC measures exceed the returns in the initial two years. However in the long term, the three SWC measures are profitable to farmers on gentle to moderate slopes and with low to medium opportunity costs of labour. It was also found that SWC measures are not financially attractive to most farmers with off-farm activities and other sources of income. It is concluded that high investment costs and initial negative returns are the major hindrances to the adoption of SWC measures by smallholder farmers in West Usambara Mountains. Options to overcome the initial investment costs include the gradual investment in SWC measures, introduction of high value crops and small credit facilities. The promotion of dairy cattle under zero grazing system can also increase the adoption of SWC measures because of the high benefits from grasses used to stabilise SWC measures

Key words: *Costs and benefits; Soil erosion; Soil and Water Conservation; West Usambara highlands; Tanzania.*

Introduction

Soil and water conservation (SWC) measures are needed to control soil erosion and sustain agricultural production on steep slopes of West Usambara Mountains. The need for SWC has resulted in the development and promotion of several SWC measures by both governmental and non-governmental programmes (AHI, 2000; SECAP, 2000; Tenge, de Graaff & Hella, 2004a). Important SWC measures that have been promoted in West Usambara Highlands include bench terraces, *fanya juu* and grass strips. Bench terraces (BT) are a series of level or nearly level platforms built along the contour lines, while *fanya juu* (FJ) are hillside ditches made by throwing excavated soil on the upper part of the ditch. They slowly accumulate soil and form terraces. Grass strips (GS) are barriers consisting of different grass species planted in strips along the contour line.

Despite decades of efforts to promote these SWC measures in the West Usambara highlands and in many other parts of Tanzania, the adoption by farmers is still minimal (Conte, 1999;

Semgalawe, 1998; Tenge et al., 2004a). Among the major reasons for low adoption in SWC could be that farmers do not recognise the losses caused by soil erosion, that recommended SWC measures are not effective or that they are not financially attractive in view of farmers' objectives and other opportunities (de Graaff, Valk & Fleskens, 2001; Jones, 2002; Tenge et al., 2004a).

Establishing SWC measures competes with other activities for scarce resources like labour and equipment. Unlike the results of other investments, the benefits of SWC are not directly observable, they may differ among different group of farmers and may take a long time to be realised (Posthumus & de Graaff, 2004; Shiferaw & Holden, 1998). The critical question facing farmers is whether the benefits of a given SWC measure are worth the costs. For these reasons, farmers need to be well informed on costs and benefits of SWC in terms of yields or monetary values in order to be motivated to invest in SWC activities. However, such information is limited or not existing in many developing countries like Tanzania (Tengberg & Stocking, 1997; Wiig, Aune, Glomsrød & Iversen, 2001)

Objectives

This research contributes to the development of a tool for the participatory appraisal of soil and water conservation measures for farm level planning in the East African highlands. The major objectives of this paper are to assess the financial efficiency of bench terraces, *fanya juu* and grass strips under different circumstances, as applied in the West Usambara highlands, and to assess under which physical and socio-economic conditions the respective SWC measures are profitable to different farmer groups. This research was undertaken in close collaboration with the farmers.

Characteristics of the research area

This research was conducted in Kwalei area, located at 4°48'S, 38°26'E in the humid warm zone of West Usambara Mountains in Lushoto, Tanzania (Figure 1). The area is representative for other highland areas in terms of agricultural potential, farming system, soil degradation problems and as a source of water for down-stream communities.

The total area of Kwalei is 500 ha with an estimated population of 4120 (Lyamchai, Owenya, Ndakidemi, & Massawe, 1998). Kwalei receives rainfall in two seasons with a total annual amount of about 1000 to 1200 mm per year. However, due to greater variations in topographic features and slope aspects the rainfall amount in the zone, which Kwalei represents, can range from 800 to 1700 mm per year (Pfeiffer, 1990). The long rainy season is from March to May and the short rainy season from September to November.

Agriculture is the major economic activity in which over 80% of people in the area are involved. The farm size ranges from 0.5 to 3 ha (Tenge et al., 2004a) but decreases due to a population increase of 2.8% per year (Lyamchai et al., 1998; URT, 2002). Soil erosion and nutrient mining compound the land scarcity problem by causing more land to become unproductive (Lyamchai et al., 1998; Meliyo, Kabushemera & Tenge, 2003; Tenge, Okoba, Sterk & Hessel, 2004b). Major cash crops are coffee, tea and various vegetables. Maize, bananas and beans are the major food crops. Tea is grown as monocrop while banana and coffee are intercropped. Vegetables are grown during the dry season in the valley bottoms where they are irrigated. Maize is grown in the long rainy season while beans are grown in both long and short rainy seasons. The main livestock types are cattle, sheep and goats. Because of the steep slopes of up to 60%, farming activities are considered not sustainable unless SWC is undertaken (Lyamchai et al., 1998; Meliyo et al., 2002; Tenge et al., 2004b). Elder farmers recall that there has been a progressive decline in crop yields over the past years. Major reasons for the yield decline are loss of soil fertility, soil erosion, poor rainfall, pests and diseases and poor agronomic practices. About 73% of households reported a decline in crop yields. Relatively few farmers (23%) reported an increase in their crop yield, due to better cropping practices such as use of fertilizers, SWC measures and improved crop varieties (AHI, 2001).

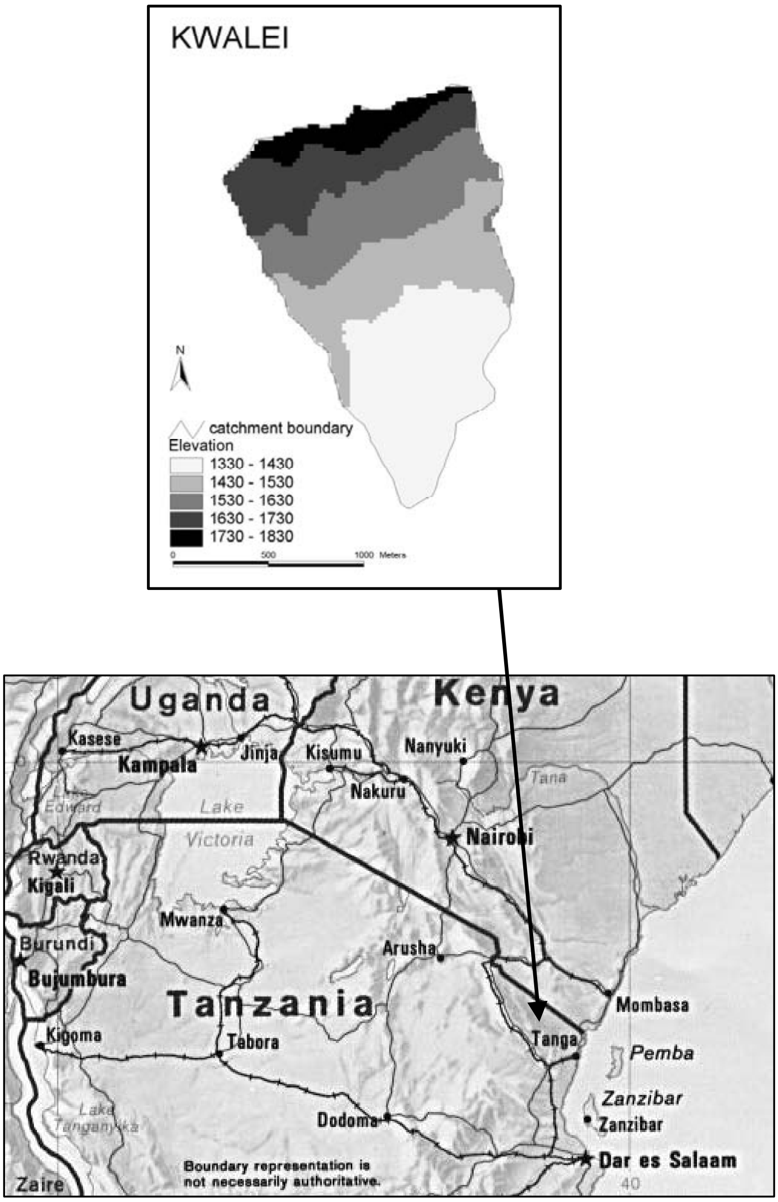

Figure 1. *Location of the research site- Kwalei*

Research Methodology

Data collection

Cost benefit analysis of soil and water conservation measures requires an in depth understanding of the extent of the effects of soil erosion and the effectiveness of soil and water conservation to reduce soil erosion and to increase crop yields and other benefits. These effects are translated into financial terms in relation to social and economic factors such as opportunity costs of labour, prices of inputs and output and farmers' time preferences.

Information on the effectiveness of SWC measures was obtained from field experiments conducted in the study area and reported by Tenge et al. (2004b). In these experiments, the physical effectiveness of bench terraces, *fanya juu* and grass strips was compared with the without conservation situation with regards to the retention of soil, retention of water and increase in crop yields. Additional information on the physical effectiveness of SWC measures was collected from a household survey and PRA reports (Lyamchai et al., 1998; Tenge et al., 2004a). Discussions with extension staff in the field of SWC and with farmers, who had implemented SWC measures, were used to verify, update and collect some missing information from the reports. The type of information, which was collected included different methods of SWC, spacing of SWC measures, type of stabilisation and the loss of cultivable area. Other information included type of crops, yield trends and the input and output levels for each SWC measure and for the without SWC situation. Information on labour, materials and equipment required for each operation to establish, produce and maintain the SWC measure was also collected.

Methods of data analysis

Data analysis consisted of three steps: categorisation of farmers, translating the impacts of SWC into monetary terms and comparing the costs and benefits for each respective group of farmers.

Grouping of farmers

Different farmers have different opportunity costs of labour and time preferences (Enters, 1998; Kuyvenhoven & Mennes, 1989). It is therefore important to categorise farmers in respective groups before performing cost benefit analysis. Cluster analysis was used to classify farmers into groups with similar characteristics that influence the costs and benefits in implementing SWC measures (Gomez-Limon & Riesgo, 2004; Kachigan, 1991). The analysis was done using the SPSS computer program (Norusis, 1990). Criteria for clustering were household characteristics and resource availability and use. Household characteristics were sex, age, household size, location, education level and marital status. Resource endowment characteristics included the extent of off-farm activities, labour availability, remittances from outside, number of cattle, farm size and type of crops that are grown. The agglomerative method (Norusis, 1990; Kachigan, 1991) was used in cluster analysis to group households based on the smallest distance between them in variables selected for clustering. The clustering was done in hierarchical order starting with extent of involvement in off-farm activities, farm size, labour availability and then sub-groups based on the combination of age, tribe and sex of the head of household.

Identification of costs

Data from field experiments, formal and informal surveys were itemised into costs and benefits. Costs included labour, equipment and materials for establishment, maintenance and production of each of the three SWC measures (GS, BT and FJ) and without SWC situation. Investment costs included labour and equipment for layout, construction and stabilisation of risers. Equipment for layout consisted of line levels, poles and *panga* while for construction hand hoes (*jembe*) and spades are needed. Annual maintenance costs were assumed to be equal to four percent (4%) of the investment costs for bench terraces and *fanya juu* and 2% of the investment costs for grass strips. Production costs included labour and materials required at the following production stages: land preparation, manuring where applicable, planting, weeding, fertilization where applicable, harvesting and transport. Maize and beans are the crops that have been considered in this research because of their importance as food crops and the high erosion rates on fields with these crops.

The change of productivity approach was used to establish costs of soil erosion and benefits of conservation (Pagiola, 1993; Barbier & Bishop, 1995; Pimentel, Harvey, Resosudamo, Sinclair, Kurz, McNair et al., 1995). In this approach, the erosion damage was considered equal to the value of the lost crop production valued in market prices. Based on field data and farmer interviews an annual productivity decline of 2% for maize and 1% for beans were assumed to occur because of soil erosion. Equipment for investment and production activities were assumed to have an economic life of three years and all the three measures were analysed over a period of 15 years. This economic life was also considered for grass strips and *fanya juu* since these eventually develop into terraces.

Identification of benefits

Benefits included all gains in current and future production caused by implementing the respective SWC measure. The effects of SWC measures on retention of soil, nutrient and water were considered to be reflected in an increase in crop yields and other outputs, such as fodder for livestock. SWC was assumed to increase crop yields from present levels without conservation to the average yields attained on farmers' conserved fields. All bench terraces and *fanya juu* were considered to be stabilised by grasses, which are sold as fodder at market prices. It was also assumed that SWC measures are maintained properly and that the maximum crop yields attained remain constant for the economic life of the respective measure. All the costs and benefits were quantified to their measurable parameters. The costs and benefits were assessed according to slope and soil types, which determined the size and spacing of the measures as indicated in equation 1.

$$H.I = (100*VI/S) \quad (1)$$

Where HI = Horizontal distance between two terraces (m).

S = Slope (%).

VI = Vertical interval between terraces (m), 1.8 for stable soil and 1.3 for unstable (loose) soil in the study area (Kizughuto & Shelukindo, 2002).

Loss of cultivable area was obtained from field measurements of the area occupied by risers for the bench terraces, ditch and embankment for the *fanya juu* and grasses for the grass strips. Five slope classes were considered: gentle (5-12%), moderate (13-25%), strong (26-35%), steep (36-55%) and very steep (>55%). However, for each slope class an average of the minimum and maximum slope values were used in calculations. The results from calculations were compared with field-measured values. Soils were classified based on the structure into unstable (sand and loam) and stable (clay).

Valuation of the costs

All the costs were converted into monetary values using their respective quantitative terms and market prices. Labour cost was considered as the product of the number of labour days (LD) required for a particular operation and the opportunity cost for each respective farmer group. According to the farmers, one labour day was equal to five working hours in the field. The opportunity costs of labour varied depending on season, possibilities for off-farm employment and availability and sources of labour (Enters, 1998; Gittinger, 1984; de Graaff, 1996). Based on group of households and the wage rates in the study area, three opportunity costs were applied; low (US$ 0.8/LD), medium (US$1/LD) and high (US$ 1.2/LD) which are respectively 80%, 100% and 120% of the average amount paid to farm hired labour in the study area. The 120% was also equivalent to average earnings per day for households employed in off-farm activities. Low opportunity costs of labour were applied to farmers with sufficient labour and no other employment opportunities; medium for households who have not sufficient labour and high in case of farmers with off-farm activities. These opportunity costs of labour also reflect the variations in labour costs to the same farmer but in different seasons and for different sources. Costs for the equipment and materials were obtained as the product of quantity required and the market price. All the prices referred to what farmers pay at the point of sale within the research area. Summation of all the costs resulted in the total costs for the respective SWC measure.

Valuation of the benefits

All the benefits were converted into monetary values by multiplying the benefits in quantitative terms by their corresponding market prices. All the benefits were added to obtain the total production value.

Cost-Benefit Analysis

Evaluation of the efficiency of the respective SWC measures was performed using the Financial Cost-Benefit Analysis (FCBA) method (Enters, 1998; Gittinger, 1984, Kuyvenhoven & Mennes, 1989). FCBA was performed for farmers with the three opportunity costs of labour and for fields at five slope classes and with two soil types. Future benefits of SWC measures were expressed in present value using discount factors at an interest rate of 5%, 8% and 13%. Three interest rates were used to represent the variability in interest rates farmers may pay when borrowing money, the differences in time preference among farmers and also due to the difficulty in specifying the actual discount rate for each farmer group. The three rates were selected based on the average interest rate from the financial institutions within the research area (URT, 2004). Efficiency criteria in the CBA were net present value (NPV) and internal rate of return (IRR). NPV is the difference between net present benefits and net present costs while IRR is the average earning power of the money used in the project over the project life (de Graaff et al., 2001). SWC measures with positive NPV and IRR greater than the respective discount rate were considered to be profitable and financially attractive to the respective farmer groups.

Sensitivity analysis
The ability of each SWC measure to withstand changes in both physical and socio-economic conditions was analysed from the FCBA results with different combinations of slope, soils, labour costs and discount factors. These variables were subjected to sensitivity analysis because of their greatest impact on the costs and benefits.

Results and discussion

Groups of farmers

The classification of farmers according to household characteristics and resources availability and use resulted in three major household groups with different opportunity costs of labour (Table 1).

Group I consisted of households with no off farm activities, small farm size (< 1 ha), but with sufficient labour force (> 3 family members). The age of heads of household in this group ranged from young (18-35 years) to old (46-60 years). This group had a low opportunity cost of labour because of sufficient family labour and lack of opportunities for off-farm employment. Group II consisted of households also with no off-farm activities but with medium (1-2 ha) to large (>2 ha) farm size.

Table 1. *Major farm household groups in Kwalei*

Characteristics	Household group		
	Group I	Group II	Group III
Off-farm employment	No	No	Yes
Farm size* (ha)	Small	Medium Large	Small Medium
Labour force** (persons)	Medium Large	Small Medium	Small Medium
Age of head of household*** (years)	Young Medium Old	Young Medium Old Very old	Young Medium Old
Ethnic	Sambaa, Mbugu	Sambaa, Mbugu	Sambaa, Mbugu
Sex	Male Female	Male, Female	Male Female

*Small: < 1ha; Medium: 1-2 ha; Large: >2ha
**Small: 1-2 Labour force; Medium: 3-6 Labour force; large: > 6 Labour force
*** Young: 18-35 years; Medium: 36-45 years; Old: 46-60 years; Very old: > 60 years

Unlike group I, this group does not have sufficient labour force (1-2 family members) for farm activities and it consists of households in all age categories from young to very old (>60 years). This group was classified to have medium opportunity costs of labour because it uses hired labour at the prevailing wage rates. Group III consisted of households who depend more on off-farm activities than on agriculture for their living. These were employees in different institutions, nearby tea estate farms and small businesses. This group was assigned the high opportunity cost of labour because it was assumed that they will be engaged in SWC conservation activities only if the returns from SWC measures are higher than from the off-farm activities. In all the three groups there were both female and male-headed households, from the main tribes of *Sambaa* and *Mbugu*. Other characteristics were found to vary within the groups.

Soil erosion and soil and water conservation measures

A soil erosion survey in Kwalei has indicated that more than one third of the area is exposed to high and very high erosion and fields planted with maize and beans are most eroded. Survey results indicate a progressive yield decline with time (Figure 2).

Although other factors could be contributing to these yield decline, discussions with key informants, extension staff and farmers provided evidence that soil erosion is one of the major causes. Low crop yields even in seasons with good rains, change of soil colour to reddish and appearance of sub-soils, which are less fertile, were some of the evidences of soil erosion.

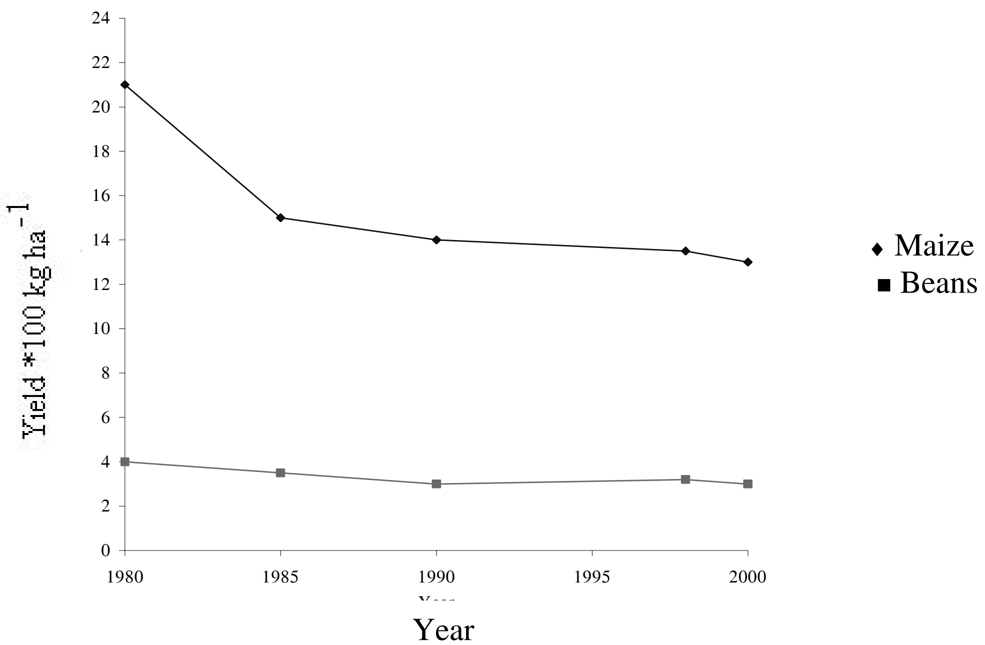

Figure 2. *Yield trend of maize and beans for 20 years in Kwalei*
Source: Field data, 2003; Lyamchai et al., 1998.

Important SWC measures according to farmers' ranking are bench terraces, *fanya juu* and grass strips. Others are cut-off drains, infiltration ditches, and agroforestry.

Although farmers are aware of the soil erosion problem, only 20% of households have undertaken SWC measures on their fields (Tenge et al., 2004a). Among the farmers who use SWC measures 55% use grass strips, 26% bench terraces and 15% use *fanya juu*. In some cases grass strips are planted as an initial stage for construction of *fanya juu* or bench terraces. In contrast to grass strips, most of the *fanya juu* and bench terraces are not older than 4 years. The need for soil conservation at the catchment scale is discussed at the village level meetings but the implementation of these SWC measures is at individual farmers' fields. Public areas such as roadsides and footpaths are often not considered and have become a major source of surface runoff to crop fields. The layout of the SWC measures is according to the Agricultural extension services guidelines, though in few cases grass strips were wider spaced than the recommendations and in several cases on slopes steeper than the recommended.

Physical effectiveness

Results in Table 2 show the effectiveness of the three SWC measures in retention of soil moisture, reduction of soil loss and increase in crop yields.

Table 2. *Physical effectiveness of SWC measures in reduction of soil loss and moisture retention in Kwalei*

Season	SWC measure	Soil loss ($t\ ha^{-1}$)	Soil moisture (%)
Short rains	Bench terraces	3.0	35.9
	Fanya juu	1.9	32.9
	Grass strips	6.2	29.2
	Without	9.6	28.5
Long rains			
	Bench terraces	3.1	34.3
	Fanya juu	0.8	27.1
	Grass strips	8.3	26.0
	Without	15.0	25.7

Source: Tenge et al., 2004b

Moisture retention

The results show that all the three SWC measures were effective in retaining soil moisture compared to the without conservation situation. Bench terraces were more effective by retaining more moisture than *fanya juu* and grass strips. Average moisture retention levels varied from 34 to 36% for bench terraces compared to respectively 27 to 33% for *fanya juu* and 26 to 29% for grass strips. This implies that if other situations remain constant crop yields are expected to be higher on bench terraces than on other SWC measures.

Soil loss

The results on soil loss provide sufficient evidence that the recommended SWC measures are effective in reducing soil loss compared to the without SWC situation. SWC measures reduced an annual soil loss from 25 $t\ ha^{-1}$ on fields without SWC situation to 15 $t\ ha^{-1}$ between grass strips, 6 $t\ ha^{-1}$ on bench terraces and 3 $t\ ha^{-1}$ on *fanya juu*.

Crop yields

Crop yields from the experiments and from farmers fields with the typical cropping system of maize and beans are shown in Table 3.

The results show a significant increase in maize and beans yield in fields conserved by bench terraces and *fanya juu* in comparison with the without conservation situation. Results from field experiments show that bench terraces increased maize yield by 1100 kg ha^{-1}, *fanya juu* by 710 kg ha^{-1} and grass strips by 180 kg ha^{-1}, against an average yield of 1250 kg ha^{-1} without a SWC measure. The increase in beans yield due to SWC measures was 90 kg ha^{-1} on bench terraces, 100 kg ha^{-1} on *fanya juu* and 20 kg ha^{-1} between grass strips, with average yield of 150 kg ha^{-1} on fields without SWC measures. The results also indicate a higher increase in maize yields from experimental plots than in farmers' fields with the same SWC measures. This is due to the differences in management and input levels, which were higher on experimental fields than under normal farmers' conditions. These differences in yield between farmers' and experiment fields support the recommendations by extension services that SWC structures alone may not increase crop yields unless other proper management practices are followed.

Table 3. *Average yield levels from farmers' and experimental fields with and without SWC measures*

Crop #	SWC Measure	Yield levels (100* kg ha^{-1})			
		Farmers fields n = (4 x) 12		Experiment fields n = 16	
		Mean	Std†	Mean	Std
Maize	Without	12.5	2.3	15.7	3.0
	Grass strips	16.2	4.2	17.3	4.7
	Bench terraces	25.2	3.4	26.7	8.4
	Fanya Juu	18.8	2.5	22.8	7.1
Beans	Without	1.5	0.3	1.8	0.5
	Grass strips	2	0.9	2.0	0.5
	Bench terraces	2.1	2.3	2.7	1.1
	Fanya Juu	2.8	2.2	2.8	1.3

Maize is grown in long - and beans in short rainy season; † Std = Standard deviation.

Source: Field data; 2003; Tenge et., 2004b

Factors affecting costs and benefits

Loss of cultivable area

Establishment of SWC measures results in a reduction of cultivable land, because of occupation by the risers and/or waterways. This can be a constraint to adopt SWC measures by farmers with small parcels of land like in the West Usambara highlands. Results in Table 4 show the loss of cultivable area for bench terraces, *fanya juu* and grass strips.

With *bench terraces* the cultivable area is reduced by 5% to 42%, depending on the slope and stability of the soil. There is more reduction in cultivable area for unstable soils than for stable soils and this reduction increases with an increase in slope steepness due to the closer spacing of bench terraces. Considering a household with a farm size of 0.5 ha, these results imply that only 0.29-0.48 ha will be available for the intended crops. These may reduce the financial benefits of bench terraces unless risers are used for high value crops to compensate for the lost area. The results support farmers' reluctance to adopt SWC measures because of the fear that their already small fields are taken by SWC measures (Tenge et al., 2004a). These results are comparable to FAO (1979), which shows that the loss of cultivable area due to bench terraces can range from 7% to 53%. Ekbom (1995) estimated a loss of 5% to 22% due to bench terraces on slopes of 12% to 56% in Muranga district, Kenya. Because of this loss in cultivable area, FAO (1979) has recommended that bench terraces should not be constructed on slopes above 30% for arable crops. On the other hand it has been argued that the increase in yield compensates for the loss of area due to construction of bench terraces (AHI, 2001).

Table 4. *Reduction of cultivable areas for the three SWC measures, by soil type and slope*

Variables		Reduction of cultivable area		
Soil type	Slope (%)	Bench terraces (%)	Fanya juu (%)	Grass strips (%)
Stable soil	5-12	5	8	1
	13-25	11	10	3
	26-35	17	19	5
	36-55	25	26	8
	>55	31	40	13
Unstable soil	5-12	7	8	2
	13-5	15	16	4
	26-35	23	25	7
	36-55	35	36	10
	>55	42	40	15

With f*anya juu* there is a loss in cultivable area ranging from 8% to 40% depending on the slope and soil type. The size and lost area is almost the same as with bench terraces because of the same spacing in *fanya juu* as in bench terraces. However, in actual field measurements it was observed that *fanya juu* occupied slightly more area than the bench terraces because of the extra area occupied by the ditch. The loss of cultivable area in *fanya juu* can also be compensated by planting appropriate crops (e.g. tree species, banana) in the ditches and grasses on the embankment.

Establishing *grass strips* leads to losses of cultivable land of only 1-15%. The lost area from grass strips is smaller than from the bench terraces and *fanya juu* because in grass strips there are no risers or ditches. These results are in agreement with Shively (1999) who reported a loss of 11% to 15% of cultivable area from hedgerows on slopes of 10%.

Labour requirements

Labour requirement to establish SWC measures is a critical item, which farmers consider in implementing certain SWC measures. Results on labour requirements for establishing bench terraces, *fanya juu* and grass strips are shown in Table 5.

The time needed to establish *bench terraces* ranges from 66 to 592 labour days per hectare (LD ha^{-1}) depending on the slope and stability of the soil. The increase of labour requirements with the slope and stability of the soil is due to closer spacing. These results are comparable to the findings by Cruz, Francisco & Tapawan-Conway (1988) in Philippines where labour requirements for bench terraces were 500 LD ha^{-1}. The number of labour days per hectare on steep slopes is more than the number of labour days available per year. This means that even if the farmer spends all days in one year the construction of bench terraces in a farm of one hectare will not be completed. But generally, SWC measures are established on plots of less than 1 ha and on average a household will have at least two household members who can work on the same field. A farmer with a field size of 0.1 ha on a very steep slope will therefore need only 59 labour days and with at least two household members this seems to be feasible.

Table 5. *Labour requirements for establishment of the three SWC measures on two soil types and five slope categories*

Variables		Labour requirements per ha		
Soil type	Slope (%)	Bench terraces (LD ha^{-1}) ‡	Fanya juu (LD ha^{-1})	Grass strips (LD ha^{-1})
Stable	5-12	66	43	7
	13-25	148	97	15
	26-35	237	155	24
	36-55	354	222	35
	>55	427	281	43
Unstable				
	5-12	92	60	10
	13-25	205	134	21
	26-35	328	215	32
	36-55	491	322	49
	>55	592	388	59

‡ LD = Labour day.

Labour requirements for establishment of *fanya juu* range from 43 to 388 LD ha^{-1}, also depending on the slope and stability of the soil. The labour requirement is less for *fanya juu* than for bench terraces because of the differences in the amount of earth to be removed. However, this result needs to be interpreted with site specific information as in some cases it may be easier to move soil down-slope with bench terraces than upslope with the *fanya juu*. For instance, in the study of the performance of selected SWC measures in Ethiopia and Eritrea, Herweg and Ludi (1999) reported that *fanya juu* was more labour intensive than soil bunds because of moving the soil uphill.
Labour required to establish *grass strips* range from 7 to 59 LD ha^{-1}. This is lower than the labour requirements for establishing bench terraces and *fanya juu* because establishing grass strips does not involve moving the soil. The results are comparable to the observation by Nelson, Cramb, Menz & Mamicpic (1998) who reported a labour input of approximately 60 LD ha^{-1} to establish contour hedgerows on sloping land in the Philippines.

Equipment and materials
The results on equipment and material costs for investment showed no significant difference between the three SWC measures. This is because the same type of equipment is used for all the three SWC measures. Total costs for equipment and materials to establish the respective SWC measures on moderate slope and for farmers with moderate opportunity costs of labour are US$ 54 ha^{-1} for bench terraces and for *fanya juu,* and US$ 55 ha^{-1} for grass strips. The equipment and material costs are lower than the labour costs for all the three SWC measures.
This suggests that the equipment and material support that is occasionally provided by extension services to support farmers (Johansson, 2001), as an incentive, may not have great impact, as the major cost in implementing SWC measures is labour.

Benefits
The benefits from the three SWC measures in this research were identified to be an increase in crop yields and the introduction of grasses on the risers and strips. A field survey indicated that farmers with no dairy cows sell the fodder at a price of US$ 0.15 per bundle of approximately 25 kg. Considering the low input and management requirements for grasses compared to management requirements for maize and beans this can be more profitable than the annual crops in the long run.

Financial Cost Benefit Analysis (FCBA)

Cash flow

SWC measures may differ in time to benefit the farmer, it is therefore important that farmers are aware of the time after which the respective SWC measures will start benefiting them. Results in Figure 3 show the cash flow over 15 years for the three SWC measures on stable soil, moderate slope and for farmers with three opportunity costs of labour.

For the establishment of *bench terraces* under the above-mentioned conditions a total of US$ 215 ha^{-1} is required in year zero (0). The results also show that it takes at least two years before the farmer can realize a positive cash flow from bench terraces. This is because of the high investment costs and the initial decline in yield caused by soil disturbances during construction (Tenge et al., 2004b). This was also observed by Ekbom (1995) in Muranga district in Kenya, where the net benefits obtained for the first three years were the highest on fields without soil conservation measures. During this waiting period a total of US$ 169 in the first year and US$ 60 in the second year are required to sustain the farmer. Considering that the majority of households in the study area are constrained by cash, this initial negative return can be a major hindrance to adopt bench terraces. Labour sharing groups, financial incentives or credit facilities are possible solutions. Alternatively these losses may become bearable by the gradual establishment of the bench terraces over a number of years depending on farmers' resource availability.

The investment costs for *fanya juu* in year 0 amount to US$ 165 ha^{-1}. Although the investment costs are less than for the bench terraces, there is still a negative cash flow of US$ 136 in the first year and US$ 26 in the second year of production. This is because of the relatively small yield increase on *fanya juu* than on bench terraces.

The results show that *grass strips* have the lowest investment costs (US$ 84 ha^{-1}). However, due to a low increase in crop yields, there is still a negative return for the first year amounting to US$ 85 ha^{-1}. Even after overcoming the initial investment costs, the cash flow from grass strips is still lower than the other two SWC measures. The low investment costs and relative short term benefits support field observations that grass strips are constructed as steps towards establishment of *fanya juu* and bench terraces.

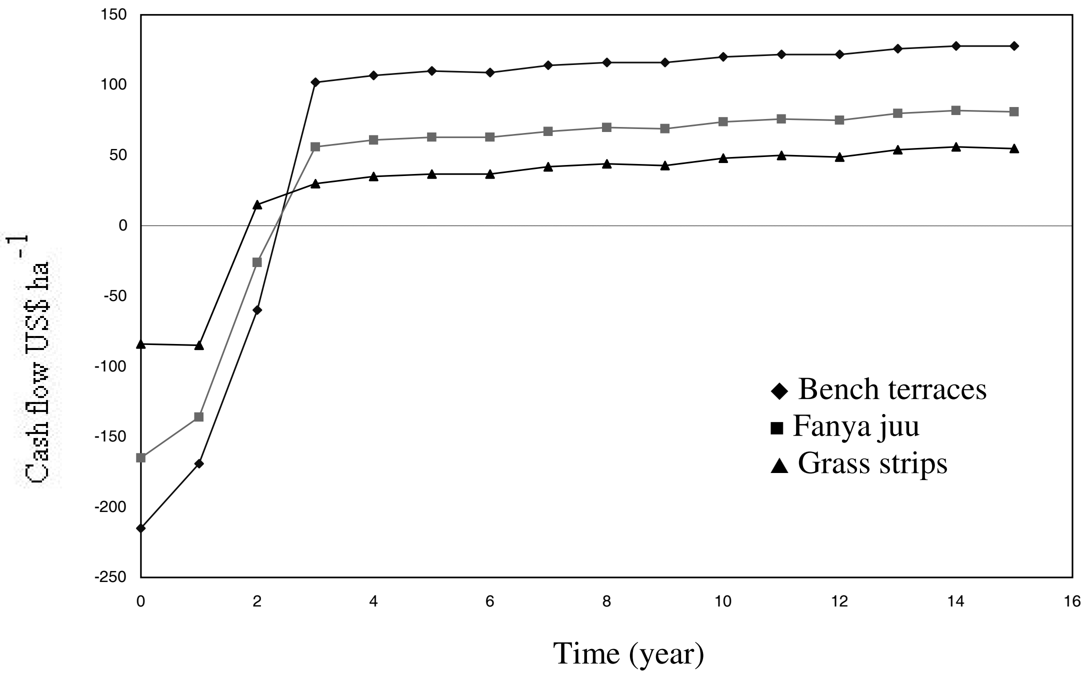

Figure 3. *Cash flow over 15 years for the three SWC measures on stable soil, moderate slope and for farmers with moderate opportunity costs of labour.*

Financial efficiency of SWC measures

The results of FCBA over fifteen (15) years of *bench terraces* and for farmers with three opportunity costs of labour are shown in Table 6.

The results show that it is financially attractive to construct bench terraces on gentle to steep slopes for farmers with low opportunity costs of labour (Group I) on both stable and unstable soils. Farmers with medium opportunity costs of labour (Group II) will financially benefit from bench terraces on gentle to moderate slopes on unstable soils and up to strong slopes on stable soils. In case of farmers with a high opportunity cost of labour (Group III), bench terraces are financially attractive on gentle and moderate slopes on stable soils and only on gentle slopes on unstable soils. These results are similar to observations by de Graaff (1981) in Jamaica where bench terraces were financially attractive to advanced and intermediate farmers only on slope ranges of 7% to 25%. Posthumus and de Graaff (2004) also have reported that profitability of bench terraces in Peru depended among others on the type of farmer and the crops grown.

The results of financial cost benefit analysis for the *fanya juu* show that in the long term *fanya juu* are financially attractive to farmers with low opportunity costs of labour on gentle to strong slopes on unstable soil and up to steep slopes on stable soil (Table 7). Farmers with medium opportunity costs of labour will financially benefit from *fanya juu* on gentle and moderate slopes for both stable and unstable soil. The results also show that for farmers with high opportunity costs of labour, *fanya juu* are only financially attractive on gentle slope.

Table 6. *Financial efficiency (NPV and IRR) of bench terraces on four slope categories, two soil types and for farmers with three opportunity costs of labour (I-III)*

Soil	Slope	IRR			NPV at 8%		
	(class)	I*	II	III	I	II	III
		(%)	(%)	(%)	(US$ ha^{-1})	(US$ ha^{-1})	(US$ ha^{-1})
Unstable	Gentle	30	26	22	576	495	415
	Moderate	21	14	7	436	213	-10
	Strong	15	6	Neg.**	282	-96	-474
	Steep	10	Neg.	Neg.	82	-499	-1081
Stable	Gentle	33	30	27	608	559	510
	Moderate	25	19	14	506	354	204
	Strong	19	11	5	396	132	-132
	Steep	14	4	Neg.	251	-160	-570

*I= 80% of wage rate, II =100% of wage rate, III=120% of wage rate

**Neg. = Negative value

Table 7. *Financial efficiency (NPV and IRR) of Fanya juu on two soil types and for farmers with three opportunity costs of labour (I-III)*

Soil	Slope	IRR			NPV at 8%		
	(%)	I*	II	II	I	II	III
		(%)	(%)	(%)	(US$ ha^{-1})	(US$ ha^{-1})	(US$ ha^{-1})
Unstable	Gentle	22	18	15	292	219	146
	Moderate	16	9	1	218	12	-193
	Strong	12	1	Neg. **	136	-214	-565
	Steep	9	Neg.	Neg.	30	-510	-1049
Stable	Gentle	23	21	19	309	265	222
	Moderate	18	13	7	255	116	-23
	Strong	15	6	Neg.	196	-47	-291
	Steep	11	0	Neg.	119	-261	-641

*I = Labour costs 80% of wage rate, II= labour costs 100% of wage rate, III= Labour costs 120% of wage rate. ***Neg. = Negative value.*

The financial analysis results show that *grass strips* are financially attractive to farmers with low opportunity costs of labour on gentle to steep slopes for both stable and unstable soil types (Table 8).

Table 8. *Financial efficiency (NPV and IRR) of Grass strips on four slope categories, two soil types and for farmers with three opportunity costs of labour (I-III)*

Soil	Slope	IRR			NPV at 8%		
		I*	II	III	I	II	III
	(%)	(%)	(%)	(%)	(US$ ha^{-1})	(US$ ha^{-1})	(US$ ha^{-1})
Unstable	Gentle	18	13	7	193	101	-2
	Moderate	16	5	Neg. **	171	-56	-264
	Strong	14	Neg.	Neg.	148	-207	-541
	Steep	12	Neg.	Neg.	123	-413	-950
Stable	Gentle	19	15	11	198	124	71
	Moderate	17	6	Neg.	182	-39	-136
	Strong	15	3	Neg.	165	-98	-341
	Steep	14	Neg.	Neg.	143	-240	-624

*I = Labour costs 80% of wage rate, II= labour costs 100% of wage rate, III= Labour costs 120% of wage rate **Neg. = Negative value

These results contradict the current recommendations based on physical effectiveness, which limit grass strips to only gentle slopes (Kizughuto & Shelukindo, 2002). This is due to the financial benefits that could be realized from grasses, which are less affected by soil erosion and are not considered in physical recommendations. This explains why some farmers use grass strips even on steep slopes where it is technically not recommended. The results also show that grass strips are financially attractive to farmers with medium opportunity costs of labour on gentle and moderate slope on stable soil but only on gentle slopes on unstable soil. Farmers with high opportunity costs of labour can use grass strips only on gentle slopes on unstable soil and up to moderate slope on stable soil.

Table 9. *Financial efficiency (NPV and IRR) of three SWC measures on stable soil, moderate slope, for three discount rates and for farmers with medium opportunity costs of labour*

SWC measure	Discount rate	NPV	IRR
	(%)	(US$ ha^{-1})	(%)
Bench terraces	5	559	
	8	354	19
	13	143	
Fanya juu	5	221	
	8	116	14
	13	5	
Grass strips	5	163	
	8	-39	6
	13	-88	

Results in Table 9 show that bench terraces have the best internal rate of return (19%) followed by *fanya juu* (14%) and grass strips (6%). These results suggest that, farmers who are able to invest in bench terraces, will be able to recover their investment faster than from the *fanya juu* and grass strips.

Conclusions

The results from this research have shown that bench terraces are more costly to establish than *fanya juu* and grass strips. However the financial returns are in the long run higher from bench terraces than from *fanya juu* and grass strips.

The three SWC measures are financially attractive under the following biophysical and socio-economic conditions: Bench terraces to farmers with low opportunity costs of labour on gentle to steep slopes for both stable and unstable soils. But financially profitable to farmers with medium opportunity costs of labour only on gentle to moderate slopes on unstable soil. If the soil is stable bench terraces are profitable to the farmer with medium opportunity costs of labour up to strong slopes.

Farmers with high opportunity costs of labour can financially benefits from bench terraces only on gentle slopes for unstable soils and up to moderate slopes for stable soil.

Fanya juu are financially attractive to farmers with low opportunity costs of labour on gentle to steep slopes on both unstable and stable soil. For farmers with medium opportunity costs of labour *fanya juu* is financially profitable only up to moderate slopes. Farmers with high opportunity costs of labour can financially benefit from *fanya juu* only on gentle slopes.

Grass strips are financially attractive to farmers with low opportunity costs of labour up to steep slopes on both stable and unstable soil but only on gentle slopes for farmers with medium opportunity costs of labour. Farmers with high opportunity costs of labour can only use grass strips on gentle slopes and stable soil.

Although the three SWC measures are financially attractive to farmers under the specified conditions, the majority of them have often limited capital to invest in SWC measures. Small-scale credit schemes, labour sharing groups and stepwise construction of the SWC measures can overcome the high investment costs. Farmers can also increase benefits of SWC measures by growing high value crops with proper management practices.

Promotion of dairy cattle under a zero grazing system will increase the adoption of SWC measures because of the high benefits from grasses. However, this will also need an improved marketing system for milk and other outputs associated with SWC measures.

Although a financial analysis is important, it is not the only criteria on which a farmers' decision to implement SWC measure is based. Other criteria and factors of adoption need also to be looked into.

This research focused on the on-site effects at the farm level. But there may also be off-site effects, when soil erosion is not prevented at the farm level, crosses the boundary and causes damage to downstream land users and infrastructure. Stakeholders considered that such effects were not of major importance in this area.

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Chapter 5

THE USE OF MULTI-CRITERIA ANALYSIS FOR THE APPRAISAL OF SOIL AND WATER CONSERVATION MEASURES: A CASE STUDY IN WEST USAMBARA HIGHLANDS

The use of multi-criteria analysis for the appraisal of soil and water conservation measures: a case study in West Usambara highlands.

Introduction

Soil erosion poses a serious economic and environmental concern in many parts of Tanzania highlands. The West Usambara highlands are among those areas experiencing soil erosion problems (Semgalawe and Folmer, 2000; Kizughuto and Shelukindo, 2003; German, 2004). Various soil and water conservation measures have been proposed for sustainable land use that can mitigate soil erosion and promote the welfare of the small scale farmers. Important SWC measures that have been promoted in the area are bench terraces, *fanya juu*, grass strips, cut-off drains, ridge and furrows, trashlines, mulching, macro-contourlines and various forms of agroforestry.

Current recommendations on SWC measures to implement are based on their physical effectiveness (Kizughuto and Shelukindo, 2002) and in few cases on financial efficiency (Tenge et al., 2004c). These evaluation approaches although useful by themselves are limited by several factors. The assessment of the physical effectiveness requires data that may not be available or are too expensive to collect. And the determination of the financial efficiency relies on monetary valuation while not all impacts of erosion/conservation can be easily translated into monetary terms (Gittinger, 1984; Erenstein, 1999). Furthermore land users have other objectives than reducing soil loss and maximizing financial benefits. Often these objectives are conflicting, which implies that there is no single SWC measure that can give best results for all land user objectives and that achieving of one objective is only possible if another is achieved to a lesser extent.

Availability of several SWC alternatives, conflicting objectives and evaluation criteria of land users hamper decision making and limit adoption of SWC measures. An alternative approach that integrates physical effectiveness, financial efficiency and other land user's objectives is required to evaluate and select appropriate SWC measures for each category of land user.

Since the 1980s Multi-Criteria Analysis (MCA) has gained popularity as a tool for making planning decisions that involve complex environmental, social and economic issues (Nijkamp et al., 1990; Van Pelt, 1993; Bogardi and Nachtnebel, 1994; Beinat and Nijkamp, 1998). MCA is a systematic way of making choices according to objectives and available options. It does not rely on monetary values and can use both qualitative and quantitative measurements. In these ways, MCA offers a great potential to address the short comings of other SWC evaluation methods. However, its application in SWC planning in particular for developing countries has not been thoroughly explored.

Research objectives

The main objectives of this research is to explore the possibilities of applying MCA in a participatory way for decision making about the most preferred SWC options. Attention is hereby given to physical effectiveness, financial efficiency and other objectives of land users in West Usambara highlands, Tanzania.

Multi-Criteria Analysis

Multi-Criteria Analysis is a tool for simplifying complex decision –making tasks, which involve many stakeholders, diversity of possible outcomes and many, sometimes intangible, criteria by which to assess the outcome. Different approaches and techniques exist for MCA (Nijkamp and van Delft, 1977; Dodgson et al., 1998). All the approaches make the options and their contribution to the different criteria explicit, and all require the exercise of judgement. They differ however, in how they combine the data. Which MCA techniques to use will differ depending on type of decision, time to undertake the analysis, amount and nature of the data available, analytical skills of those supporting the decision and differences in administrative and cultural requirements. The general analytical steps in MCA are described hereunder.

Step 1: Determination of objectives
The first step in MCA involves setting of objectives, where for example all stakeholders state what they require from the land under consideration. The objectives indicate the direction of state of change of a system desired by the decision maker (s). These objectives should be clear (specific, measurable, agreed and realistic). According to Bogardi and Nachtnebel (1994), there are three possible ways to improve an objective: maximizing it, minimizing it or maintaining it at an existing position. These objectives can be conflicting if an increase in the level of one objective can only be achieved by decreasing the attainment level of another objective.

Step 2: Identification of alternative options
Once the objectives are identified and defined, the second step is to identify options that may contribute to achieve these objectives. The alternatives should be independent and should compete more or less about the same resources.

Step 3: Determination of the evaluation criteria
The third step is to decide on how to compare the contributions of the different options toward the objectives. This requires selection of criteria to reflect performance in meeting the objectives. Each criterion must be measurable in the sense that it must be possible to access at least in qualitative sense how well a particular option is expected to perform in relation to the criterion. The criteria should represent all the major aspects but should not count an aspect more than once.

Step 4: Determination of the effects
At this stage, the effects of the alternatives are assessed according to the measurable criteria set at step 3. The step involves answering the questions on how will the effects be identified and measured.

Step 5: Standardisation of the effects.
This step aims at eliminating the influence of different dimensions in which each criteria has been expressed. The scores for each criteria have to be expressed in the same unit of measurement. Such transformation to the same units is called standardisation. There are two well-known standardisation methods (Eq 1 & 2). Method 1 (Eq. 1) is recommended if a ratio scale has been

used. Method 2 (eq. 2) if an interval scale has to be transformed (Voogd, 1985; de Graaff et al., 2001).

$$e_{ji} = s_{ji} / \max s_j \qquad (1)$$

$$e_{ji} = \frac{s_{ji} - \min s_j}{\max s_j - \min s_j} \qquad (2)$$

where
e = standardised criterion
i = alternative i
j = criterion j
s = unstandardised score
max s_j = highest score of criterion j
min s_j = lowest score of criterion j

Method 1 implies that the criteria with the highest unstandardised score has always the standardised score of 1. In method 2 always standardized scores of 0 and 1 occur. If a criteria has a negative effect, the standardised score is calculated as ($1-e_{ji}$).

Step 6: Formulation of weights
Different criteria usually have different levels of importance to each land user. This is expressed by the weights attached to each criteria. It is therefore necessary to incorporate some form of criteria weighting to take care of their relative importance. These weights can be established directly by interviewing people concerned or indirectly by expert judgement from previous choices or actual behaviour in the past (Nijkamp et al., 1990; de Graaff, 1996).

Step 7: Aggregation and ranking.
Step seven involves combining the weighted scores for each alternative. There are different MCA methods, each with their own way of aggregation (Filius, 1993; Bogardi and Nachtnebel, 1994). It includes both multigoal programming and methods that address discrete choice of problems. For participatory appraisal of interventions such as SWC, the later category is to be used. One of the most used methods of combining weights is the additive weighting method (Eq. 3). The total weighted scores are then arranged according to the size. The alternative with the highest value of total scores (P_i) is the best alternative.

$$P_i = \sum_{j=1}^{J} w_j * e_{ji} \qquad (3)$$

Where
P_i = score of alternative i
w_j = weight to criterion j
e_{ji} = standardised score of criterion j for alternative

Materials and methods

Research area

The research site is Kwalei Catchment located in the humid warm zone of West Usambara highlands,Tanzania. The total area of the catchment is 5 km^2. The catchment borders Baga natural forest reserve on the north. The catchment is about 12 km from Soni town in the southern part of Lushoto district, Tanga region. It is situated at an altitude range of 1000-1600 m. It has steep slopes up to 60% and medium mountains with narrow valley bottoms (Meliyo et al., 2002). The catchment receives a bimodal rainfall pattern with annual amount ranging from 1000-1200 mm. The long rain season is from March to May and the short rain season from September to November. The average temperature ranges between 18-23^{0}C with maximum in March and minimum in July (Wickama and Mowo, 1999).

Kwalei catchment consists of 12 sub-villages with a total of 516 households with an estimated population of about 4120 people (Lyamchai et al., 1998). Over 80% of the people in the catchment depend on agriculture for their living. Major cash crops are coffee, tea and various vegetables. Maize, bananas and beans are the major food crops. Tomatoes and other vegetables are grown on the valley bottoms and lower slopes where irrigation is possible while maize, coffee and banana are grown on hill/ridge summits of upper slopes. The main types of livestock are cattle, sheep and goat. The household land size ranges from 0.5 to 3 ha. Soil erosion and related problems are among the major constraints to agricultural production in the area (Lyamchai et al., 1998; Meliyo et al., 2002).

Other economic activities include trade (mini-shops, mini-restaurants, milling machine etc), vocational jobs (carpentry, masonry, tailoring etc) and employment in government and non-governmental institutions. Important institutions that deal with natural resources management include village/catchment leaders and government agents dealing with Agricultural extension services, Agricultural research and Foresty management. There are other institutions outside the catchment but closely associated or linked to the community, that can influence natural resources management. These include: Herkulu Tea Estates, Mponde Tea estate, Sakarani farms and Bumbuli hospital.

Data collection

Data for this research was collected through group discussions, household interviews and field experiments. Important actors were identified from the PRA report conducted earlier in the catchment (Lyamchai et al., 1998). These were small scale farmers of different categories and government agents dealing with natural resources management. Through group discussions and household surveys, farmers were asked about their objectives regarding land uses. Similarly, government agents through interviews were asked their objectives on land use. Several discussions were held with farmer groups and 104 household heads were interviewed. Three government officials representing agricultural extension and agricultural research were also interviewed. The major roles of agricultural extension officers in the catchment were to promote appropriate agricultural technologies ranging from crop varieties, management and soil erosion control. Agricultural researchers work together with farmers, extension staff and other stakeholders to find solutions for problems in agricultural production. At the time of this research major research activities were related to finding the best approach for dissemination of agricultural technologies and collective actions for watershed management (German, 2004; Mowo et al., 2004). The government land use policy was also reviewed to have a broad overview of the government objectives.

During the household surveys and group discussions, farmers were asked to mention different SWC measures that can be used to achieve the specified objectives and their criteria to select appropriate SWC measures for implementation. SWC options and the criteria mentioned by farmers during the household survey were compiled by the researcher and presented for discussion by a group of 24 farmers representing all the 12 sub-villages in the catchment. These representative farmers (key informants) were selected by all farmers during the village meeting. Selection criteria were based on their knowledge of the catchment and their experiences on farming and on SWC measures. During discussions with this group of key informants some SWC alternatives and criteria were ommitted because they were not feasible or represented more or less the same objectives.

Data on the physical effectiveness was collected from detailed field experiments conducted in the area (Tenge et al., 2004b; Chapter 3), from farmers who have been implementing SWC measures for a long time and from extension staff dealing with SWC measures. Financial efficiency of the SWC measures was obtained from the results of the Financial Cost Benefit Analysis (FCBA) of major soil and water conservation measures (Tenge et al., 2004c; Chapter 4).

Data Analysis

Data analysis involved identification of the most important SWC options and formulation of weights for each criteria by the actors. This was followed by aggregation and ranking using MCA. Farmers (key informants) analysed SWC measures by giving scores to each criteria on the scale of 1 for not good and 4 for very good. SWC measures with the highest total scores were short listed for the integrated analysis using MCA. Farmers (key informants) determined the relative importance of each criteria by a pairwise ranking method (Defoer and Hilhorst, 1995). The results of farmers' ranking were expressed as weight, which is the ratio of the total scores for individual criteria to the overall scores for all criteria (Belton and Reeves, 2002). Government officials used an indirect method by assigning weights to each criteria based on their experience. The average values were used in MCA. The additive weighting or weighted summation method was used to obtain the total weighted scores for each alternative. The alternative with the highest total weighted scores was considered as the most preferred to that particular actor(s) in land management (de Graaff et al., 2001). Sensitivity of the ranking was assessed by comparing the results of qualitative measurements by farmers and those from experiments. Ranking results using the five individual cost and benefit criteria were also compared with results obtained by use of a single financial efficiency criterion: the net present value (NPV), as derived from Chapter 4.

Results and discussion

Major actors and their objectives

There are two major groups of actors in the catchment: The target farm households and the government agencies acting among others on behalf of future generations. During the discussions with farmers and government agents a total of 12 criteria were mentioned, on the basis of which they would assess SWC measures (Table 1). These criteria are categorized into physical effectiveness, financial efficiency and others.

Physical effectiveness

Three main criteria were mentioned for evaluation of the physical effectiveness of SWC measures. The criteria reflect that farmers would like SWC measures that are effective in reducing soil loss and that can improve soil fertility not only by retaining soil but also by retaining or adding nutrients. An other physical effectiveness criterion was water conservation for plant use during dry spells.

Financial efficiency

Five criteria were identified and agreed to be used in evaluating the finacial efficiency of the proposed SWC alternatives. These constitute the major benefit and costs aspects. Farmers were of the opinion that some SWC measures prevent soil loss without improving crop yields. Others compete with crops for the moisture and affect negatively the crop yields. Therefore they would prefer SWC measures that increase crop yields. They also preferred SWC measures that will provide fodder for their animals and reduce the work load for search of fodder. Costs of SWC measures in terms of materials and labour for both construction, maintenance and production were also considered as important criteria to evaluate SWC alternatives.

Other criteria

Farmers preferred SWC measures that will make it possible to irrigate crops on steep slopes either by reducing the slope or by harvesting and conveying water. SWC measures should not make farm operations more difficult by blocking passages or changing ploughing orientation. Farmers will also evaluate SWC measures on the basis of the possible time to implement. SWC alternatives that can be implemented during the period of low labour demand for other activities are preferred. The alternatives should be simple to establish and to be maintained with a minimum requirement of technical skills.

The objectives and the list of criteria by farmers and government agents in Kwalei catchment did not reflect the commonly perceived conflicts between different land users such as downstream and upstream farmers (de Graaff et al., 2001). This is because downstream farm land (valley bottoms) is cultivated during the dry season when there are no surface runoff effects from upstream plots. Besides upstream and down stream plots may also belong to the same farmer (Tenge et al., 2004a). The selection of criteria also reflects that farmers more often considered the field rather than the catchment scale.

Table 1. *Farmers' and government objectives and criteria with regards to soil and water conservation measures in Kwalei catchment*

Objectives	Criteria	Unit of measurement
Physical effectiveness		
Soil conservation	Minimize soil loss	t ha^{-1} per year
Improve soil fertility	Minimize nutrient loss	kg ha^{-1}
Water conservation	Maximize moisture retention	Moisture content (%)
Financial efficiency		
Increase crop yields	Maximize crop yield	kg ha^{-1}
Fodder production	Maximize fodder production	kg m^{-1}
Labour inputs	Minimize labour requirement	LD† ha^{-1}
Materials inputs	Minimize material costs	US $ ha^{-1}
Minimum maintenance	Minimize maintenance costs	US $ ha^{-1}
Others		
Irrigation	Maximize irrigation possibility	Rank
Simplified tillage	Maximize tillage convenience	Rank
Time of implementation	Maximize implementation period	Rank
Simplicity	Minimize skills requirement	Rank

†LD = Labour days

Soil and water conservation alternatives

Alternatives for achieving farmers and government objectives include both physical and biological SWC measures (Table 2). According to matrix ranking by farmers, the most important are bench terraces (BT), Grass strips (GS), *fanya juu (*FJ*)*, agroforestry (AG), infiltration ditches (ID) and cut-off drains (CD). Based on farmers ranking BT, FJ, GS and the without conservation situation (WO) were short listed for MCA. Detailed descriptions of these measures are presented by Tenge et al., (2004b) and in chapter 3 of this thesis. Evaluation of all the measures by farmers revealed the following:

Bench terraces

According to farmers bench terraces are very good in soil and water conservation but not good in increasing crop yield and time for implementation. Farmers associated bench terraces with yield decline because they often considered only the first years after implementation. This was because not many farmers have implemented bench terraces for a long enough period to realize the long term benefits. Farmers insisted that even where there was an increase in yield, it was because of the use of manure rather than bench terraces themselves.

Fanya juu

This SWC measure was evaluated by farmers as average to good in many criteria except for time of implementation which had the same ranking as bench terraces.

Grass strips
Grass strips were ranked very good for fodder but not good for introducing irrigation.

Agroforesty
This was ranked as average to good for many criteria except for irrigation for which it had a low ranking.

Without SWC situation
Farmers evaluated the without SWC situation as good in many financial aspects. They considered it as simple and requiring less material and labour inputs. The without case has also the lowest maintenance costs and does not interfere with other farm operations. However, they gave it a low ranking for soil erosion control, for fodder and for increasing crop yields.

Infiltration ditches
Infiltration ditches were ranked very good in water conservation. This was because they are also used as water harvesting structures.

Cut off drains
These were ranked high in easy tillage because one cut off drain can protect large pieces of land without fragmentation of the land. But they were ranked as not good in many other aspects such as fertility improvement and irrigation.

Trashlines
These were ranked very good with regard to time for implementation because they are made during the dry season after harvesting when the labour demand for other activities is low. Trash lines were also ranked as good for fertility improvement because the trash materials add organic matter to the soil. But they were evaluated as not good with regard to material inputs because crop residues are also used as animal feed hence there is competition.

Ridges
Farmers evaluated ridges as good for material inputs but not good for easy tillage as they block the passages. They also ranked ridges as not good in maintenance as they have to be re-constructed each season.

Deep tillage
This was evaluated as good for material and labour inputs and average to not good with regard to other criteria.

Table 2. *Farmers' ranking of different SWC options in Kwalei catchment, Tanzania*

Criteria	Scores‡ for Soil and water conservation options									
	BT	FJ	GS	AG	WO	ID	CD	TRL	RG	DT
Physical effectiveness										
Soil loss	4	3	2	2	1	2	2	2	2	2
Nutrient loss	2	2	2	3	1	2	1	3	2	1
Moisture retention	4	3	2	2	1	4	2	2	2	2
Financial efficiency										
Crop yields	1	2	2	2	1	2	1	2	2	2
Fodder production	4	4	4	3	1	1	1	1	1	1
Labour costs	2	3	3	3	4	1	3	2	2	3
Material costs	2	2	3	2	3	2	2	1	3	3
Maintenance costs	3	3	2	2	4	3	3	1	1	1
Others										
Irrigation possibility (I)	4	3	1	1	1	2	1	1	1	1
Easy tillage (T)	3	3	3	3	4	2	4	2	1	2
Time of implementation(TI)	1	1	2	3	3	1	1	3	3	1
Simplicity (SI)	2	2	3	3	4	3	3	3	2	2
Overall score	32	31	29	29	28	25	24	23	22	21
Rank	1	2	3	3	5	6	7	8	9	10

‡Scores 4= Very good, 3 = Good, 2 = Average, 1 = Not good.

BT= Bench terraces, FJ = Fanya juu, GS = Grass strips, AG = Agroforestry, WO = Without, ID = Infiltration ditches, CD = Cut off drains, TRL = Trash lines, DT = Deep tillage, RG = Ridge.

Evaluation criteria and weights

Farmers

The relative importance of evaluation criteria and weights given by farmers are indicated in Table 3. The results show that farmers attach a relatively high importance to effectiveness in soil erosion control, water conservation and improvement of soil fertility. Other important criteria are increase in crop yields and provision of fodder. Other criteria have on average a lower weight but can be important for some farmers.

Government

Table 4 shows government priorities on criteria to evaluate SWC. Government agencies have the same criteria as farmers but they differ in the importance attached to each. From the government point of view important criteria are reduction of soil loss, yield increase, improvement of soil fertility, fodder, irrigation possibilities and water conservation. The results indicate that government agencies give relatively low importance to labour costs involved in implementing these SWC measures. Government agencies also do not attach much importance to the time of implementation and how the proposed SWC measures will affect other tillage operations.

Table 3. *Farmers' pairwise ranking of SWC evaluation criteria*

Criteria	Pair-wise ranking												Score	Weight
	SC	F	TL	W	I	FO	Y	SI	TI	LI	MI	MN		
Soil loss (S)	x	S	S	S	S	S	S	S	S	S	S	S	11	0.16
Nutrient loss (F)		x	F	F	F	F	F	F	F	LI	F	F	9	0.13
Easy tillage (TL)			x	W	I	FO	Y	SI	TL	TL	TL	TL	3	0.04
Moisture retention (W)				x	W	W	W	W	W	W	W	W	9	0.13
Irrigation possibility (I)					x	FO	Y	I	I	I	I	I	6	0.09
Fodder production (FO)						x	Y	FO	FO	FO	FO	FO	7	0.10
Crop yields (Y)							x	Y	Y	Y	Y	Y	8	0.12
Simplicity (SI)								x	SI	SI	SI	SI	4	0.06
Time of implementation (TI)									x	LI	TI	TI	3	0.04
Labour costs (LI)										x	LI	LI	5	0.07
Material costs (MI)											x	MI	2	0.03
Maintenance costs (MN)												x	1	0.01

Table 4. *Government ranking of SWC evaluation criteria*

Criteria	Weight
Physical effectiveness	
Soil loss	0.24
Nutrient loss	0.12
Moisture retention	0.11
Financial efficiency	
Crop yields	0.18
Fodder production	0.12
Labour costs	0.04
Material costs	0.04
Maintenance costs	0.02
Others	
Irrigation possibility	0.11
Easy tillage	0.02
Time of implementation	0.03
Simplicity	0.05

Effects of alternatives on the evaluation criteria

Physical effectiveness

The effects of alternatives on the physical effectiveness criteria are derived from the detailed physical research undertaken about the respective SWC measures (Tenge et al., 2004b, Chapter 3). The results on the effects of the SWC measures on the evaluation criteria are shown in Table 5. These results show that *fanya juu* is very good in reducing soil erosion followed by bench terraces. Bench terraces are very good for moisture retention and in increasing crop yields. The without SWC situation is not good in all aspects of physical effectiveness. These results are slightly different from farmers' ranking (Table 2). For instance farmers ranked bench terraces as better than *fanya juu* in reducing soil loss but not good for increasing crop yields. This observation implies that there is a knowledge gap or difference in perception on the effects of the proposed alternatives.

Financial efficiency

The effects of the alternatives on financial efficiency are derived from the detailed farm survey and experiments (Tenge et al., 2004c; chapter 4). The results in Table 5 show that bench terraces are more efficient than other alternatives with regard to yield but not good in labour and maintenance needs. The without SWC option is not good with regard to yields but has of course low costs. This is conform farmers' perception, as indicated in Table 2, that the without situation is simple and requires less labour and material inputs.

Table 5. *Effects of SWC alternatives on evaluation criteria in Kwalei catchment*

Objectives	Criteria and units	Scores of alternatives on criteria			
		BT	FJ	GS	Without
Physical effectiveness					
Soil conservation	Soil loss (t ha^{-1})	6	3	15	25
Improve soil fertility	Nutrient loss (kg ha^{-1})	2	1	4	20
Water conservation	Moisture retention (%)	34	30	28	27
Financial efficiency					
Increase crop yields	Maize yield (kg ha^{-1})	2700	2300	1700	1600
Fodder production	Fodder production (kg m^{-1})	25	25	25	0
Labour inputs	Labour costs (LD† ha^{-1})	363	312	255	144
Material inputs	Materials costs (US $ ha^{-1})	106	106	115	17
Minimum maintenance	Maintenance costs (US $ ha^{-1})	129	99	30	0
Others					
Irrigation	Irrigation possibility (Rank‡)	4	3	1	1
Simplified tillage	Tillage convenience (Rank)	3	3	3	4
Time of implementation	Slack period (Rank)	1	1	2	3
Simplicity	Skills requirement (Rank)	2	2	3	4

†LD = Labour days. ‡Rank: 1 = Not good, 2 = Average, 3 = Good, 4 = Very good.

Other objectives

The other criteria can only be expressed in qualitative terms and therefore ranking was applied. Bench terraces were ranked better for irrigation potential, but these were not good for time of implementation because they have to be implemented after the rainy season while farmers have other activities. The without SWC option was considered the most simple and more convenient for time of implementation

Ranking of the alternatives

The integrated evaluation results (Table 6) show that for both farmers and the government agents the four alternatives are ranked in the same order: bench terraces, *fanya juu*, grass strips and the without situation (WO). Bench terraces and *fanya juu* come very close. The ranking results were not different whether qualitative or quantitative measurements were used. Also the use of NPV instead of several financial efficiency criteria did not affect the order of ranking. Given the different criteria weights to each group, this was not expected. However, only two categories of stakeholders were included, which had not many conflicting objectives.

Table 6. *MCA ranking of the SWC measures for Kwalei catchment, by two actor groups*

Criteria	Weighted scores							
	Government agencies				Farmers			
	BT	FJ	GS	WO	BT	FJ	GS	WO
Physical effectiveness								
Soil loss	0.18	0.21	0.10	0.00	0.12	0.14	0.06	0.00
Nutrient loss	0.11	0.11	0.10	0.00	0.12	0.12	0.10	0.00
Moisture retention	0.11	0.10	0.09	0.09	0.13	0.11	0.11	0.10
Financial efficiency								
Crop yield	0.18	0.15	0.11	0.11	0.12	0.10	0.08	0.07
Fodder production	0.12	0.12	0.10	0.00	0.10	0.10	0.08	0.00
Labour costs	0.00	0.01	0.01	0.02	0.00	0.01	0.02	0.04
Materials costs	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.03
Maintenance costs	0.02	0.02	0.00	0.00	0.01	0.01	0.00	0.00
Others								
Irrigation possibility	0.03	0.02	0.00	0.00	0.09	0.07	0.00	0.00
Simplified tillage	0.02	0.02	0.02	0.02	0.05	0.05	0.05	0.06
Time of implementation	0.01	0.01	0.02	0.03	0.01	0.01	0.03	0.04
Simplicity	0.00	0.00	0.03	0.05	0.00	0.00	0.04	0.06
Total	0.78	0.77	0.58	0.35	0.75	0.73	0.57	0.40
Rank	BT>FJ>GS>NO				BT>FJ>GS>NO			

Discussion

Results from this research have indicated that unlike other approaches where government agents are the planners and farmers the ones who implement, MCA analysis can provide room for both farmers and government agents to interact and participate in defining the objectives and criteria to appraise SWC measures. In MCA, conflicts between land users such as downstream and upstream farmers can be dealt with in order to reach a compromise between the conflicting parties. But in Kwalei the downstream effects were not considered as criteria by the farmers and government agents, because the downstream farmland is cultivated during the dry season when there is no surface runoff from upstream plots.

The fact that for some criteria the qualitative assessment by farmers on the effects of alternatives was different from the research results implied that there is a knowledge gap (or different perception) on the effects of the SWC measures among the farmers. This observation also indicates that qualitative information may be subjective and biased and this will affect the ranking. Therefore, for the assessment of the effects of the alternatives on the physical effectiveness criteria, use is made of the results of the physical research, although this has been rather costly and will not be easy to replicate.

The effects of SWC measures under different situations of farmers such as slopes, soil types, opportunity costs of labour etc. do not show up in this analysis, because only average values have been used in this application of MCA. But such further analysis may give more insight into the conditions under which the SWC measures are preferred above each other.

Farmers and government agents attached different weights to the same criteria but the results showed the same order of importance for alternatives for both farmers and the government agents. This observation pinpoints to the fact that the two actor groups had not many conflicting interests and that with the weighted summation method a single criterion with the highest score can influence the overall results.

MCA also does not accommodate for the timing of the costs and benefits, which is important for SWC measures that take a long time for the benefits to be realised. Although it is argued that the time aspect can be incorporated in MCA by the use of efficiency criteria of FCBA such as NPV, in this research the incorporation of NPV showed more or less the same results. The facts that the effects of soil erosion or conservation are cumulative and that there are some interactions also limit the application of MCA, which requires independent objectives and criteria. For example the effects of the alternatives on the physical criteria can be taken into account by the increase in yield, which was considered as a financial criteria.

Conclusions

In this research the use of MCA for the participatory appraisal of SWC measures at farm level was explored. MCA was applied for the selection of SWC measures and then compared to other appraisal methods focussing on physical effectiveness and financial efficiency. Farmers and government agencies who are the major land use actors in the study area participated in the appraisal by identifying and defining their objectives, SWC alternatives and the criteria to evaluate the alternatives. They also participated in ranking of the criteria and the impacts of the alternatives on the criteria.

Results from this appraisal led to the following major conclusions: MCA increased the level of land use actors' participation in SWC planning by allowing them to identify the objectives, criteria and the alternatives. These objectives and the alternatives provided not only the additional information for the design of acceptable SWC measures but also made it possible to incorporate many criteria and objectives which were previously not considered. In these ways MCA proved to be a strong tool, not only in decision support but also in exploring stakeholders' viewpoints.

Despite the advantages of MCA its application may be limited by the knowledge gap on the effects of SWC measures on the criteria. The physical effectiveness was also to be assessed in a participatory way, directly by farmers, but because of the knowledge gap this seemed to lead to a very subjective judgement. The facts the MCA can not show the effects of the alternatives over time also weakens its application in SWC because many SWC measures take a long time for the benefits to be realised and this has been a big problem in convincing the farming community about the importance of SWC measures. In this application MCA did not deal sufficiently with different situations of farmers, slopes, opportunity costs etc. that are encountered in planning of SWC measures.

In view of both the advantages and disadvantages, MCA can be used in the West Usambara highlands more for participation and exploration of the actors viewpoints rather than for ranking of alternatives. The use of MCA in farm-level SWC planning, by simple integration of physical effectiveness and financial efficiency, will not make much difference compared to the use of FCBA, since in FCBA the physical effectiveness should be taken into account by the increase in yields.

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Chapter 6

APPLICATION OF PARTICIPATORY SOIL EROSION MAPPING AND FINANCIAL ANALYSIS TOOLS IN SOIL AND WATER CONSERVATION PLANNING:

PART 2: CASE STUDY OF KWALEI CATCHMENT IN WEST USAMBARA HIGHLANDS, TANZANIA

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Application of PARTicipatory soil erosion mapping and financial analysis tools in soil and water conservation planning:

Part 2: case study of Kwalei catchment in West Usambara highlands, Tanzania

Abstract

Despite decades of soil and water conservation (SWC) efforts in the West Usambara highlands and other places in Tanzania, the adoption of the recommended SWC measures by farmers is minimal. In the past efforts, SWC plans did not incorporate framer's knowledge and the economics of soil conservation was not given much attention at the planning stage. This research evaluated the applicability of two tools for participatory soil erosion mapping using farmers' indicators of soil erosion and financial analysis of SWC measures at the planning stage. The two tools were evaluated in Kwalei catchment in the West Usambara highlands, Tanzania. The participatory soil erosion-mapping tool uses farmers' indicators of soil erosion to identify, classify and map soil erosion at the catchment level. The financial analysis tool involves farmers in a stepwise analysis of the costs and benefits of SWC measures before the implementation. Results showed that the two tools were able to identified erosion affected areas within the catchment and the costs and benefits of SWC measures at the planning stage. In these ways, the two tools increased farmer's participation and helped to make an informed decision on SWC planning. With the erosion-mapping tool, farmers' awareness on the severity of soil erosion problems increased, and they realized the need for SWC plans at both field and catchment scales. With the financial analysis tool farmers participated in the cost and benefits analysis and were able to select SWC options that were feasible under their socio-economic situation. The two tools were able to demonstrate that farmers' participation in SWC planning increases the acceptance of SWC measures because they solve problems that are perceived by themselves. The financial analysis tool demonstrated how farmers could make selection of SWC measures that are feasible under their biophysical and economic condition if they are informed about they costs and benefits. Further application of the two tools is recommended under other biophysical and socio economic conditions.

Key words: *Catchment approach, soil erosion, soil erosion indicators, soil and water conservation, financial cost benefit analysis, Tanzania.*

Introduction

The African highlands are facing critical problems due to land degradation caused by free grazing and inappropriate land husbandry. The results of which are soil erosion and related problems (Thomas *et al*., 1997; Kiara *et al*., 1999; Kizughuto and Shelukindo, 2003). For a number of years various SWC measures have been developed and promoted in many parts of the East African highlands to reduce soil erosion problems and improve the livelihood of the farming communities (Liversage, 1944; Lundgren, 1993; Westerberg and Christianson, 1999). Important SWC measures are bench terraces, <u>fanya juu</u>, grass strips, micro-contour lines and different forms of agroforesty (Shelukindo and Kizughuto, 1995, Thomas *et al*., 1997; Tenge et al., 2004a). Despite the efforts to promote SWC measures, the adoption by farmers is minimal and soil erosion continues to be a problem (Denga *et* a*l*., 2000; Semgalawe *et al*., 2000; Tenge et al., 2004b) causing loss of soil fertility, low productivity and food deficiency. Other problems related to soil erosion include siltation of water ways, flooding, and damage to various structures.

Major reasons for the failure of past efforts to control soil erosion in many parts of East African highlands are the top-down approaches that were adopted by both pre- and post-independent governments (Kiara *et al*., 1999; Mowo *et al*., 2002; Asrat *et al*., 2004). In top-down approaches, farmers were considered as recipients of the SWC technologies rather than equal partners in their development and planning (Mowo *et al*., 2002). Pre-independent governments used cohesive measures to force farmers implement SWC measures (Conte, 1999a; Johansson, 2001). This made farmers hate the whole idea of soil conservation (Lundgren, 1993; Conte, 1999b; Kiara *et al*., 1999). After independence, there was no longer use of force but farmers were still excluded in the identification of soil erosion problems and in planning of SWC activities. Experts gave recommendations that were not perceived as immediate priority to farmers' needs or that did not suit their social and economic situations (Shaxson *et al*., 1989; Asrat *et al*., 2004; Tenge et al., 2004b). Locally adapted technologies were largely ignored even though they were effective (Jones and Tengberg, 2000). The results of the top-down approaches were scattered implementation of SWC measures and lack of maintenance immediately after the expert left or the concerned project ended (McDonald and Brown, 2000).

When farmers' performance did not meet the expectations, promotion of SWC measures was tried using a new approach known as catchment approach (CA). This approach has been tried extensively in Kenya (Pretty *et al*; 1995; Kiara *et al*., 1999) and in the West Usambara highlands in Tanzania (Kizuguto and Shelukindo; 2003). The main concept of the CA is to mobilize the community to implement soil and water conservation within a specific area (1-5 km^2) known as a catchment. This is perceived as an effective way to concentrate efforts and resources. The CA is implemented by selection of the area that needs conservation and then mobilization of the community through different participatory rural appraisal (PRA) tools (Theis and Grady, 1991; Kirway *et al*., 2003). A multi-disciplinary team of professionals lead farmers in participatory appraisal where different constraints in the catchment are identified and ranked in order of priorities. The time set to address soil erosion problems in a particular catchment is 12 (Kenya) to 18 (Tanzania) months. For more details on the steps that are followed in the catchment approach, see the first part of this series (Okoba *et al*., 2005).

Because of the nature of soil erosion and the related problems, which are not directly observable, only in rare cases soil erosion and conservation come out as the top priority in the PRA meetings. The time set to address SWC in a certain catchment is also too short for farmers to realize the benefits of SWC measures. With the CA, economics of soil conservation have also not often been considered in planning of soil and water conservation. Instead, SWC measures have been often assessed based on their ability to reduce soil loss and their impacts on soil properties (Gachene *et al*., 1997; Kizuguto *et al*., 2003). The information generated from this assessment is useful for planning of SWC but they are not sufficient to convince farmers to invest in SWC measures, because they are more interested in crop yields and financial implications than in the loss of soil and changes in soil properties. It is therefore difficult to motivate farmers to invest in SWC without first translating the effects of soil erosion and benefits of conservation into crop yields and financial terms (de Graaff, 1996; Lal, 1995).

Investment in SWC competes with other activities for scarce resources of labour, equipment and land. Unlike other investments, the benefits of SWC measures are not directly observable; they differ among farmers and may take long time to be realized. Because of this nature of SWC measures farmers have always been faced with critical question of whether the benefits of a given SWC measure are worth the cost, and after what time these benefits become clear. For these reasons, farmers need to be informed about the cost and benefits of conservation before implementation so that they select SWC measures that are feasible under their socio-economic situation. The success of the CA is likely to be increased if farmers' perceptions of costs and benefits of soil conservation were incorporated in planning and implementation of SWC programmes. However, information on the financial costs and benefits of SWC measures is not available in many parts of developing countries. The problem is aggravated by lack of tools for participatory assessment of the costs and benefits of SWC measures before they are implemented.

In view of the need for the participation of farmers in SWC planning and the need for cost-benefit analysis of SWC measures, two tools were developed for (i) participatory soil erosion mapping and (ii) financial analysis of SWC measures. The first tool uses farmers' knowledge and indicators of soil erosion to identify and map soil erosion, while the second tool analyses the costs and benefits of SWC measures before they are implemented. The objectives of this paper were to describe the two tools and show their application in Kwalei catchment in West Usambara highlands, Tanzania. The paper is the second in a series of two papers that describe these tools. The first tool is described in more detail in the first part (Okoba *et al*., 2005), while the emphasis in this second part is more on the description and application of the financial analysis tool.

Materials and methods

The new SWC planning tools

Two tools were developed to increase farmers' participation and improve the SWC planning at the field and catchment levels. The first tool is known as participatory soil erosion-mapping tool, while the second is referred to as financial analysis tool. The participatory soil erosion-mapping tool was developed based on the results of research with farmers in the highlands of Kenya (Okoba *et al*., 2004a). In these studies it was identified that farmers were aware of the erosion impacts which they identified using soil surface features and plant characteristics. These findings were followed by another study that established that farmers could associate the erosion indicators with soil erosion status and crop yield levels (Okoba *et al.,* 2004b).

The financial analysis tool was developed based on the results obtained from extensive physical and household survey research that was conducted in the West Usambara highlands of Tanzania. The physical research assessed the impacts of SWC measures on reduction of surface runoff, soil loss and their impacts on crop yields under different slopes and soils (Tenge *et al*., 2004a). In a separate study, household surveys were conducted to identify farm household characteristics based on which farmer groups were distinguished (Tenge *et al*., 2004b). Following these studies, the physical impacts of major SWC measures were converted into financial terms according to categories of farmers, type of crops and opportunity costs of labour (Tenge *et al*., 2004c). Results from these studies provided experiences of the variations of costs and benefits of SWC measures according to biophysical (soil, slope, erosion class, crop, etc) and socio-economic (type of farmer, opportunity costs of labour, time preferences, input and output prices) situations. These experiences led to the development of the financial analysis tool.

Short description of the participatory soil erosion-mapping tool

The participatory soil erosion-mapping tool uses farmers' knowledge and indicators of soil erosion to identify, classify and map soil erosion. The application of this tool assumes that the catchment that needs SWC already has been selected and the initial PRA to collect baseline data has been conducted during other steps of the CA.
The tool consists of six steps. The first step is the identification of the key informants from the local farmers. These farmers will lead the community in the subsequent steps in using the tool. They should be full time farmers familiar with the local environment and representative of all households within the respective sub-villages that form the catchment. The second step is the community meeting where all farmers discuss and generate a list of soil erosion indicators and their relative severity based on their perception. The third step is drawing of the catchment field map showing all farmers fields. The key informants lead in drawing of this map while the rest of the community ensures that all fields are included and laid out correctly. In the fourth step, the key informants undertake the field-by-field soil erosion survey and classify the erosion status of each field according to the observed erosion indicators. Erosion classes of all fields in the catchment are then aggregated to form the erosion map at the catchment level. Step 5 involves key informants visit to each field and attaching yield levels to each erosion class. The last step is for experts to quantify farmers' qualitative crop yield loss predictions. A village meeting can follow this step where all farmers in the catchment discuss the results. For more details on these steps, see the first part of this series (Okoba *et al*., 2005).

Full description of the financial analysis tool

This tool forms part of the participatory SWC planning procedure, which has been developed to improve the CA, and includes the participatory erosion-mapping tool. The tool is in a form of a manual with instructions and spreadsheets to enter data and simplify calculations. The tool can be applied without the use of a computer, but if available it can simplify calculations and enable analysis of different scenarios. However, the use of a computer should not replace the key concept of participatory analysis.

The financial analysis tool applies in a participatory way the basic principles of financial cost benefit analysis (Enters, 1988; Kuyvenhoven and Mennes, 1989; de Graaff, 1996). In this analysis, both socio-economic and biophysical data are required. Socio-economic data are farm household characteristics (on the basis of which farmer groups are distinguished), input and output prices, the amount of labour required for each operation to establish, produce and maintain each SWC measure, and the opportunity costs of labour. Biophysical data include soil type, slope, erosion situation, type of crops, farm location and size, yield levels, available SWC options and their impacts on crop yields. The tool is used in a stepwise approach whereby all the costs to be incurred in implementing SWC measure are identified and quantified. Benefits that are expected from SWC measure are also identified and quantified. The financial benefits are then determined by comparing the streams of benefits and costs over a number of years depending on farmer's time preferences and the life span of the respective SWC measure. When the benefits outweigh the costs, the respective SWC measure is financially profitable.

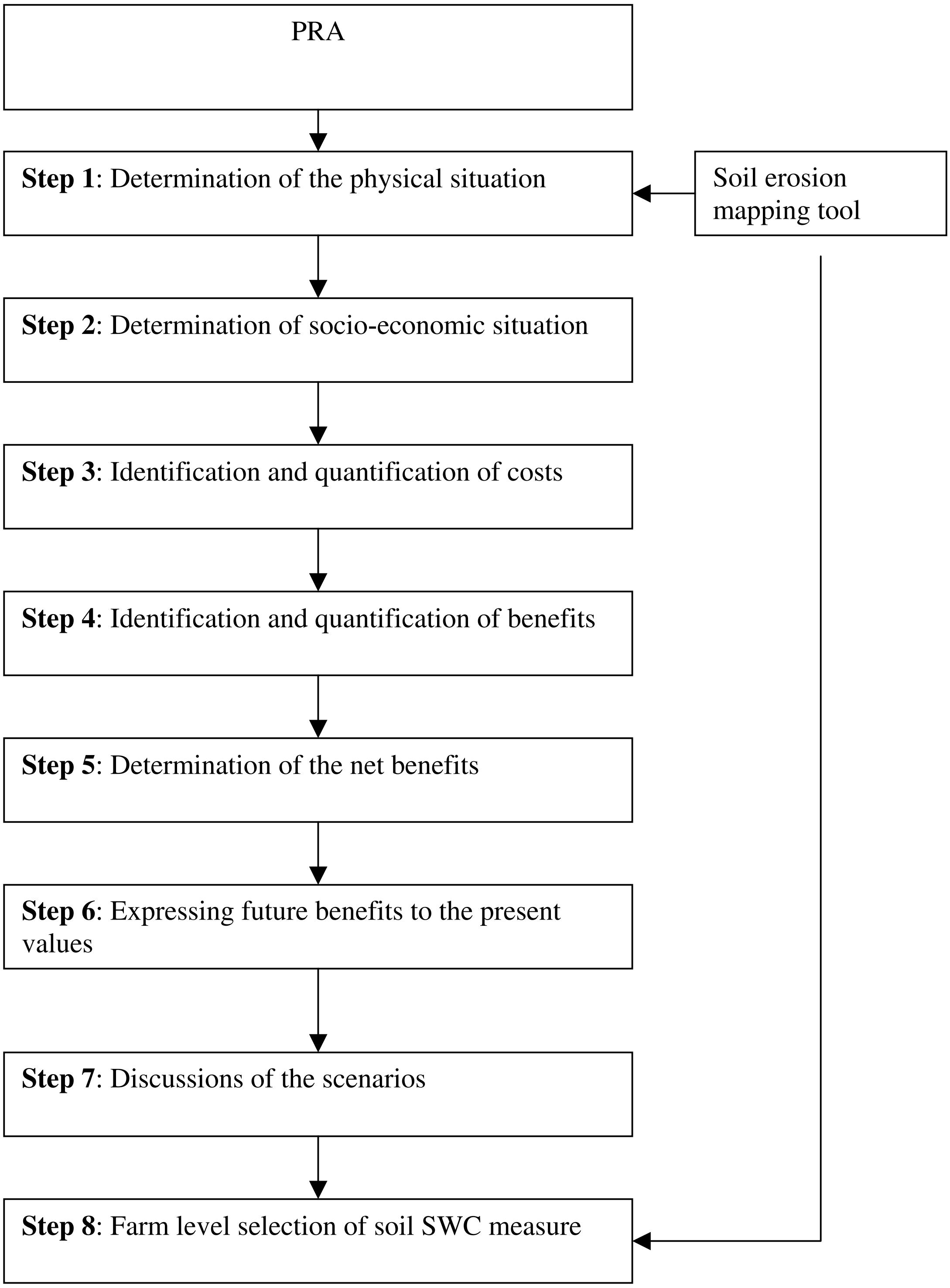

Figure 1: *Steps of the financial analysis tool for planning of SWC measures.*

The use of the financial analysis tool assumes that the soil erosion situation and the need for soil conservation have been identified using the participatory soil erosion mapping. The extension staff dealing with SWC in the catchment is responsible for leading farmers in the steps of the financial analysis tool. Later on farmers with basic training on SWC measures (village technician) can lead the other farmers in this financial analysis. The financial analysis tool consists of eight steps (Figure 1), which are described hereunder.

Step 1: The extension staff responsible for SWC measures in the catchment contact local leaders to make an appointment for a meeting with the village technician and the farmer whose fields need conservation. Village technicians are farmers who have been trained as part of the CA on basic principles of SWC measures. If the field belongs to a group of farmers with the same interest, then the appointment is made to all farmers in the group. With the help of the soil erosion status map from tool 1, the farmer locates his/her fields, and identifies the physical situations of slope, erosion class, crops, and yield levels. Village technicians will help farmers to identify biophysical conditions that are not directly observed from the erosion map, such as slope. Based on the biophysical situation of the fields and the land use intended by the farmer, the extension staff leads the discussion on the selection of SWC options for the respective fields and land use. Options from the farmer or group of farmers are also included in the discussion. If a field receives run-on from upslope, an infiltration ditch or cut-off drain is needed and therefore added to the list of SWC options. The financial analysis tool compares the benefits of SWC with reference to the without conservation situation, therefore the without conservation situation is also included in the list of SWC options selected by the farmer(s).
Output: List of biophysical situation of the field(s) that need conservation and SWC options.

Step 2: The aim of this step is to identify the socio-economic characteristics of the farm that will affect the costs and benefits of SWC. These characteristics include sources and size of labour force for implementing SWC measures, activities that are to be foregone for SWC measures and earning from off-farm activities. Other important information will be the time horizon over which to analyse the costs and benefits of SWC measures. During a meeting with the farmer, the extension staff leads the discussion that generate this information for each individual farmer or group of farmers with similar characteristics.
Output: List of socio-economic characteristics that will affect costs and benefits of SWC measures.

Step 3: The aim at this step is to identify, quantify and give monetary values to all the costs to be incurred in implementing SWC measures. In a participatory way, the extension staff, village technicians and group of farmers discuss all the operations that are required in implementing the selected SWC options. After an agreement on the operations, the type and quantity of all the equipment and materials that are required in each operation is discussed. This will differ according to the resources available to each farmer or group of farmers, therefore farmers should take a lead in this part of the discussion. The corresponding prices at the selling point for the equipment and materials should also be identified at this step. The extension staff should check with farmers during this discussion if the price list from the PRA is still valid. If not, an adjustment is required.
Identification of the equipment and materials is followed by a discussion on labour requirements for each operation agreed in the first part of the discussion. The extension staff will make use of the general information on labour costs from the PRA and make necessary corrections according to the specific situation of the individual farmer. The last part of this step is to convert all costs items into monetary value. This is also achieved through discussion, whereby the extension staff leads the farmers and village technicians to convert the cost items into monetary values by multiplying the cost items in quantitative terms by their corresponding market prices. In case of labour, labour cost is the product of the number of labour days (LD) required for a particular operation and the opportunity costs of labour for the respective farmer group. One labour day refers to the total number of hours in a day a farmer can work on the farm. Opportunity cost of labour refers to the

amount in monetary value a farmer would be paid by doing other activities. All costs are added to obtain total costs for investment, production and maintenance.
Output: List of cost items in monetary terms required for implementing SWC measures.

Step 4: This step determines the potential benefits of the SWC measures. Benefits are all gains in current and future production caused by applying certain SWC measures. They may include yield increase, fodder production, poles, fuel wood, increase in land value etc. These benefits will depend on the type of crop and the farming system practiced by individual farmers. In this step, the extension staff lead a group of farmers in the discussion of the expected benefits of the selected SWC options, farmers who have implemented SWC measures before, also share their experiences on the benefits. To make the benefits more understandable the extension staff can use some examples of benefits from other places.

The benefits for particular SWC measures selected by farmers are then quantified. This is achieved by attaching quantitative values to the measurable parameters for each of the benefit item agreed during the discussion above (e.g. yield in 10 bags, fodder production in 50 kg etc). The extension staff will lead in this quantification based on the physical information such as yield levels and erosion status from the soil erosion status map (output from tool1) and the basic input data (data obtained from PRA) on the impacts of SWC measures. Adjustments can be made based on professional experiences, information from experiences of farmers and the guidelines provided in the tool manual. All the benefits are then added up to obtain total production value (gross benefits) for each SWC option and the without SWC situation.
Output: List of expected benefits from SWC measures and their corresponding monetary values.

Step 5: This step identifies the net gains (net benefits) by implementing a certain SWC measure in comparison to the without SWC situation for a specific farm. At this step, the extension staff or the village technician makes the calculations but ensures that the farmer can understand the results. The steps involved in these calculations are: (1) to determine the net revenue by calculating the differences between total production values (output from step 4) and the total costs (output from step 3) for each SWC measure and the without conservation situation; (2) to calculate the differences between net revenue for each SWC measure and the without SWC. The difference in net revenue between SWC measure and the without conservation situation is the net gain by implementing a certain SWC measure. The net benefit is calculated for at least five years to get the cash flow trend with time for the farm.
Output: Short and long-term net benefits of the selected SWC measures as cash flow in series of years.

Step 6: This step determines the future benefits of SWC measures. Soil and water conservation may benefit the farmers more in the future than at the time of implementation. These future benefits need to be converted in present worth. Evaluation criterion in this case is the net present value, which is the current value of the future benefits. It is obtained as the product of net benefit and the appropriate discount factor. Extension staff or the village technician performs the calculation: first by selecting the appropriate discount factor provided in the tool manual and then calculating the product of the discount factor and the net benefit for each SWC measure for the agreed time horizon under consideration.

Output: Future net benefits by implementing certain SWC measures in comparison with the without SWC situation.

Step 7: This step aims at presenting and discussing the financial analysis results with the respective farmer or group of farmers. After the calculations, the extension staff and farmer(s) meet again at an agreed time. The extension staff leads the discussion by explaining to the farmer(s) the meaning of cash flow and net present values. The extension staff may use pictorial presentation in the form of chart or graphs to make sure that it is understood by the farmer(s). Examples of these graphs are provided in the tool manual.

Step 8: In this step, the extension staff presents the results for each SWC measure selected by the respective farmer or group of farmers. The implications of the results are discussed until the farmer(s) make an informed final decision on which SWC measure(s) to implement. After discussions with an individual farmer, the extension officer will organise a community meeting where all farmers in the catchment attend. In this community meeting, the extension officer shows the soil erosion map developed earlier using the participatory soil erosion-mapping tool to remind farmers of the erosion situation in the catchment. Then the financial analysis results for individual farmers are presented pointing to the specific fields on the map. With evidences from the financial analysis, attention in this discussion should be focused to the extra costs that an individual farmer has to incur because of the run-on from the upslope field or from public areas. This is discussed until farmers reach an agreement on what actions to be taken.
Output: Farmers final decision on which SWC measure(s) to implement.

Site description

The two tools were evaluated in Kwalei catchment located at 4^{o}48'S, 38^{o}26'E in the West Usambara Mountains of Tanzania. The area is representative for other highland areas in terms of agricultural potential, farming systems, soil degradation problems and as a source of water for down-stream communities. The catchment covers an area of about 5 km^2 with an estimated population of 4120 (Lyamchai *et al*., 1998; Tenge *et al*., 2004b). Kwalei catchment receives rainfall in two seasons, form March to May (long rains) and from September to December (short rains). The total annual amount of rainfall is about 1000 to 1200 mm. Agriculture is the major economic activity in which over 80% of people in the area are involved. The farm size ranges from 0.5 to 3 ha (Tenge *et al.*, 2004b) but is decreasing due to a population increase of 2.8% per year (Lyamchai *et al*., 1998; URT, 2002). Major cash crops are coffee, tea and various vegetables. Maize, bananas and beans are the major food crops. Maize is grown in the long rainy season while beans are grown in both long and short rainy seasons. The main livestock types are cattle, sheep and goats. Because of the steep slopes of up to 60%, farming activities are considered not sustainable unless SWC is undertaken (Lyamchai *et al*., 1998; Meliyo *et al*., 2002; Tenge *et al*., 2004a). Important SWC measures according to farmers ranking are bench terraces, *fanya juu* and grass strips. Other measures are cut-off drains, infiltration ditches, and agroforestry. Although farmers are aware of the soil erosion problems, only 20% of households have undertaken SWC measures on their fields (Tenge *et al*., 2004b). Among the farmers who use SWC measures 55% use grass strips, 26% use bench terraces and 15% use f*anya juu*.

Application of the tools

The two tools were applied in Kwalei catchment in June and July 2003, shortly after the long rains, and in October-December 2003, during the short rains. The timing was important to ensure that all erosion indicators were still visible. The tools are intended to be applied by agricultural extension staff working with farmers in rural areas. Professionals interested in SWC planning can also use the tools. The authors, in close collaboration with extension staff, key informants and village technicians, conducted the application of the two tools described in this paper. Village leaders played a role in organizing the community meetings and making appointments with the key informants.

Erosion-mapping tool

The agricultural extension officer introduced the researchers to the catchment area and to the village leaders. Village leaders organized the community meeting where researchers were introduced to the catchment community. During this community meeting, key informants knowledgeable with the catchment were selected to represent all sub-villages in the catchment. Transect walks were conducted by these key informants to have the physical overview of the catchment. All six steps were subsequently followed and resulted in an erosion status map for the catchment.

Financial analysis tool

Following the application of the first tool, all fields that needed conservation were identified from the soil erosion status map. For the demonstration of the financial analysis tool, a sample of thirty fields was selected to represent different biophysical situations and socio-economic situations found in the catchment. Fields with a cropping system of maize and beans were selected because they were identified to be more eroded than fields with other crops. The nine individual farmers owning those 30 fields were contacted after an appointment through their local leaders.

Results and discussion

Tool 1: Participatory soil erosion mapping tool

Identification of the key informants (Step 1)

During the community meeting 24 key informants representing the 12 sub-villages in the catchment were selected. Fifteen were male and the rest female. These key informants played an active role in the application of the two tools by leading some steps and providing general information of the catchment.

Farmers' indicators of soil erosion (Step 2)

Field transect walks and discussions on the soil erosion processes and features by the community resulted in the consensus list of soil erosion indicators. During the community meeting farmers were free and motivated to share their experiences on soil erosion indicators. The soil erosion indicators were ranked by all farmers using the pair-wise ranking method (Kirway *et al*., 2003). The relative contribution of each erosion indicator to the severity of erosion was expressed as the weight, which is a ratio of the total frequency count for an individual indicator to the overall total frequency count. These weights were used to determine the overall erosion classes in case of presence of multiple indicators. Some indicators were omitted from the list after the debate that they were not indicators of soil erosion. For example, the bracken fern weed was omitted from the list because from experiences of farmers it appeared it could grow well even on soil that is not eroded.

Table 1: Farmer's indicators of soil erosion in Kwalei catchment

Indicators	Rank†	Weight‡
Bareness	1	0.13
Gullies	2	0.11
Rock outcrop	2	0.11
Stony soils	4	0.10
Mashuhee	5	0.09
Rills	6	0.08
Soil colour	6	0.08
Surface runoff colour	8	0.07
Coarse soils	9	0.06
Plant colour	10	0.04
Steep slope (>70%)	10	0.04
Low yields	10	0.04
Broken SWC structures	13	0.02
Sedimentation	13	0.02
Loose soils	13	0.02
Root exposure	16	0.01

†Rank 1 = erosion severity is high, Rank 16 = erosion severity is low

‡Weight >0.1 = High erosion, Weight 0.04-0.1 = Moderate erosion and Weight < 0.04 = Low erosion

Results in Table 1 show the consensus list of farmers' indicators of soil erosion and their weights, which indicate the severity of soil erosion.

According to farmers, bareness, gullies, rock exposure and stoniness are indicators of high erosion rates while root exposure, loose soil and sedimentation indicate low erosion levels. Others indicate moderate erosion rates. These indicators were further grouped by farmers into those that show current erosion (rills, water colour, etc.), and those that show past erosion (gullies, bareness, etc.).

Farmers were able to explain the meaning of each indicator and under what situations of slope and soil they are commonly found. The motivation of farmers to share their experiences was attributed to the fact that their fellow farmers (key informants) led the discussions. The consensus list of soil erosion indicators mentioned by farmers in Kwalei indicates that farmers have a wide knowledge and recognise the symptoms (indicators) of soil erosion. The indicators of soil erosion in West Usambara highlands are within the indicator categories cited elsewhere (Kelly *et al*., 1998; Barrios *et al*., 2000; Okoba *et al*., 2004a). This implies that the erosion-mapping tool could be applied elsewhere with minimum adjustments.

Soil erosion map: Farmers reaction (Steps 3 and 4)

Farmers and key informants were able to use their knowledge of indicators of soil erosion and the physical environment of their catchment to draw a map showing fields and their erosion status. The farmers’ field map was not drawn to scale, but it represented the relative size and position of all fields and important features such as perennial forest, streams, footpaths, and roads. The soil erosion status map produced using farmers indicators shows three erosion classes (Figure 2). These classes were according to the type and severity of indicators present in the field during the survey. High erosion classes were found on the steep slopes and on fields with annual crops of maize and beans. Low erosion classes were on valley bottoms and fields with soil conservation structures. From the erosion map farmers were able to identify why some areas were more eroded than others, and also the sources of runoff that cause erosion.

The community was convinced that the map represented the erosion situation in their fields, except one male farmer who could not agree with the high erosion class assigned to his field. The key informants had to check their records of indicators and agreed with the farmer. The community agreed that the map has increased their understanding of the seriousness of the soil erosion problems in the catchment. For the key informants, the survey of indicators in itself improved their knowledge of soil erosion effects as they could see the impacts of erosion on fields when doing the survey. One male key informant recalled how the survey has changed his perception and awareness of soil erosion “ *Nowadays when I walk around my field and the catchment I see all erosion indicators as if they were not there before the survey*”. Farmers in Kwalei distinguished fewer soil erosion classes than found in most scientific works (Morgan, 1996; Lu *et al*., 2004). This suggests that the perception of high or low erosion may be different between farmers and scientists, which calls for a need to integrate farmers' and scientific knowledge.

Yield levels (Steps 5 and 6)

Key informants assigned yield levels to each erosion class based on their perception of erosion effects. The key informants’ predictions were evaluated by measuring yield levels from representative fields for each erosion class. The predictions by key informants were within the same range of the measured values (Table 2).

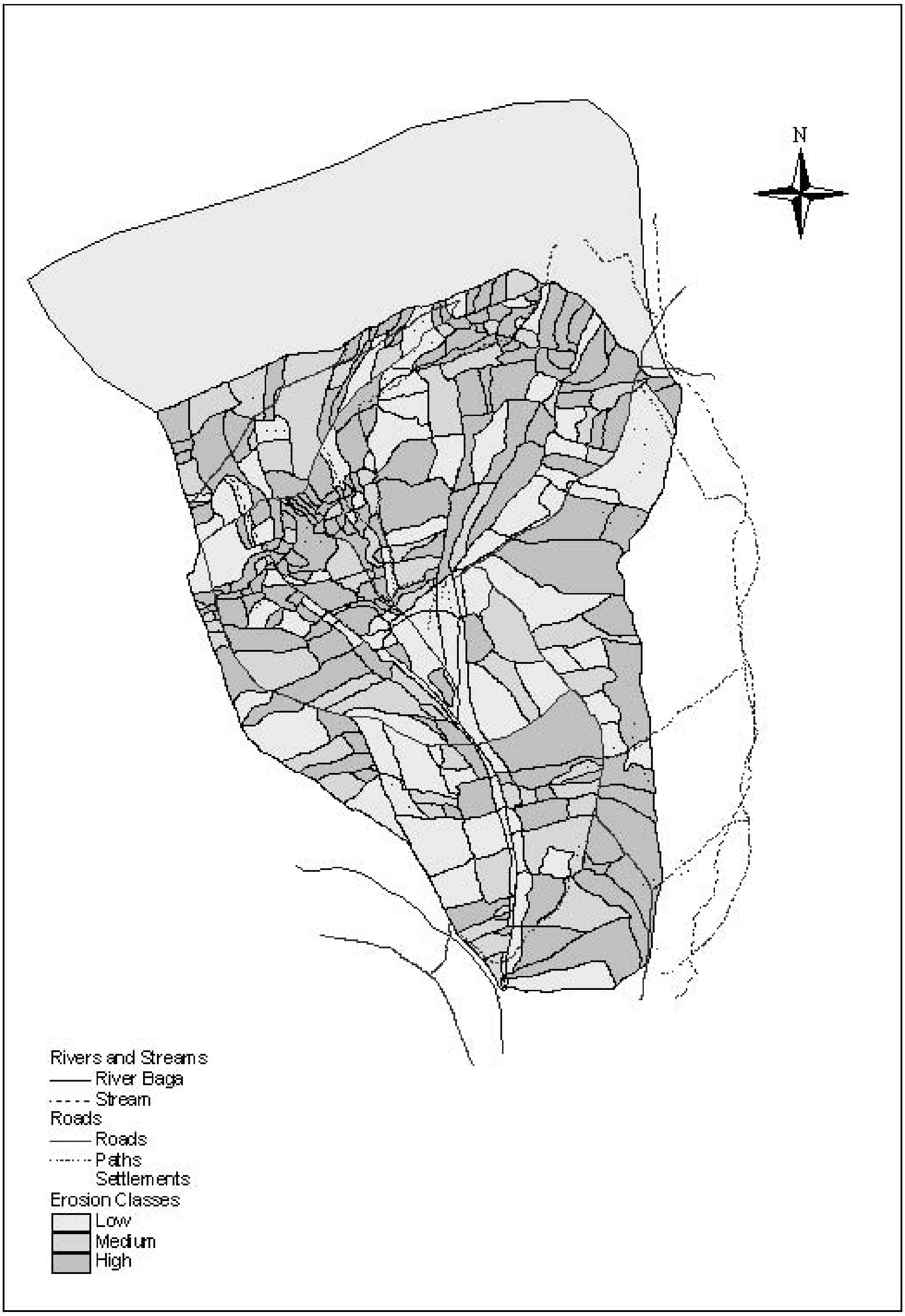

Figure 2: *Farmers' erosion status map in Kwalei catchment, Tanzania.*

Table 2: *Mean grain yield and percentage grain yield loss of different soil erosion classes in Kwalei catchment*

Erosion class	Farmers' prediction crop yield loss (%)	Measured mean yield† (t ha^{-1})	Measured yield loss (%)
High	75-100	0.9 (0.3)	70-90
Moderate	25-50	1.8 (1.2)	25-65
Low	< 25	2.0 (1.5)	13-25
Control‡		3.5 (0.4)	0

‡Reference soil where soil erosion is perceived to have had minimum effects;

†Values in parenthesis are standard deviation from the mean.

Key informants predicted a yield loss of 75-100% on highly eroded fields, compared to 70-90% from the measured values. Reactions from the community was that these values reflected the actual situation because they have been observing yield declines even during good climatic seasons, an observation which supports the common wisdom that yield decline is due to soil erosion.

From the soil erosion status map, the community noted that large proportions of their area were in the high erosion class and needed conservation. This was the starting point for SWC planning. During a community meeting, farmers discussed where to start, which conservation measures and what to do with public areas. They proposed that first SWC measures would be promoted in general village meetings where soil erosion awareness can be raised to all farmers using the erosion status map. Implementation of SWC measures according to farmers should start from the highly eroded areas (high erosion classes) and individual farmers are responsible for their own farms. In case of public areas farmers suggested that all members of the respective public area be responsible for conserving those areas. SWC options suggested by farmers were:

- *Fanya juu*, bench terraces, tree planting and infiltration ditches on steep slopes and highly eroded areas.
- *Fanya juu*, bench terraces, grass strips, fodder trees and ridge and furrows on moderately steep slopes and moderately eroded areas.
- Grass strips, ridge and furrows, cover crops and trash lines on gentle slopes and low eroded areas.

Tool 2: Financial analysis tool

Physical and socio-economic situation (Steps 1 and 2)

Using the erosion status map, it was possible to identify physical characteristics of fields that needed conservation. Characteristics that were possible to identify from the map were field location, erosion class, soil type and yield levels. Other characteristics such as field size and slopes were collected from the individual farmers. SWC options for each situation were selected from the results of the impact study conducted in the research area (Tenge *et al*., 2004a). The nine farmers owning the 30 representative fields selected a set of SWC options they preferred and the type of crops they intend to grow after conservation. Based on the biophysical and socio-economic conditions, the financial analysis tool was applied to each individual field but taking into consideration whether there was a run-on problem from the upslope field. For demonstration purposes, this paper presents results of the nine farmers.

The farms differ in size, yield levels and erosion classes of the fields (Table 3). This diversity represents the actual situation of small-scale farmers in the West Usambara highlands and indicates the likely difference in impacts of soil and water conservation measures. Comparing the yield of maize (3.5 t ha^{-1}) from the soils that are perceived to have had no effect of soil erosion (Table 2), the results from the nine selected farmers show that the current yield levels of maize and beans are generally low. This reflects the soil degradation situation in West Usambara highlands and emphasises the need for SWC conservation. In addition to maize and beans, farmers would like to stabilize the SWC structures by grasses that can be used as fodder for livestock. This change in crops after implementation of SWC measures is not only likely to increase the financial benefits of SWC measures but also will reduce the workload for search of animal feed.

Costs for implementing SWC measures (Step 3)

Through interactive discussions between farmers and the extension staff, the financial analysis tool was able to identify and quantify the cost items for implementing SWC measures. The costs were categorized into investment (preparation and construction), production, and maintenance. In each category there is cost for equipment, materials and labour. Equipment for implementing SWC measures were identified to be line levels and poles for lay out while for construction, hand hoes, *panga* and spades are needed, since all the work has to be done manually, not only because of the financial situation of farmers but also because of the steep slopes that hinder the use of simple machines. Maintenance costs, which are those costs incurred after construction to keep the conservation structure effective, were identified to involve the replanting of stabilizer grasses and cleaning of the related drainage ditches. Material inputs are those production expenses that are required in one production cycle and included animal manure, fodder grass, seeds, and for very few farmers chemical fertilizers. The extension staff was able to lead farmers through all the steps of quantification and valuation of these costs. Results in Table 4 illustrate an example of quantification of labour costs.

Results on the total investment costs are shown in Table 5. The results indicate that, regardless of the biophysical and socio-economic situation of the farmer, costs for investment are in decreasing order of bench terraces, *fanya juu* and grass strips. Grass strips have low investment costs because of the low labour requirement in construction and the small cultivable area that is occupied by the grasses. Discussions with farmers revealed that the investment costs for the other two SWC measures are high and difficult to afford.

Table 3: *Typical input data and characteristics of sample farmers in Kwalei catchment, Tanzania*

Characteristics	Farmer								
	F28	F20	F5	F2	F7	F8	F9	F11	F12
Labour opportunity costs (US$/LD)	1	1	1	1	1	1	1	1	1
Farm size (ha)	0.72	1	0.4	0.8	0.5	0.25	0.5	0.4	0.8
Slope (%)	40	35	35	45	42	40	25	50	40
Soil	Unstable	Stable	Stable	Stable	Unstable	Unstable	Stable	Stable	Stable
Erosion class	High	Low	High	High	High	High	Moderate	High	High
Surface run-on effect	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No
Current yield maize (100 kg ha^{-1})	3.5	17.1	6	6.25	4	5	12.3	3.1	6.5
Current yield beans (100 kg ha^{-1})	0.9	0	1	0	0.8	0.8	2.1	0	1.5

Table 4: *Typical input data for labour costing in Kwalei catchment, Tanzania*

Item	Unit	Bench terraces	*Fanya juu*	Grass strips	Without conservation
Layout	m/LD†	100	100	100	0
Construction	m/LD	8	13	100	0
Plant grasses	m/LD	200	200	250	0
Land preparation	LD/ha	20	20	25	30
Manuring	LD/ha	15	15	15	16
Plant-maize	LD/ha	15	15	16	17
Plant beans	LD/ha	12	12	13	14
Weeding	LD/ha	10	10	12	15
Fertilization	LD/ha	12	12	13	14
Harvest-maize	LD/ha	15	15	16	20
Harvest beans	LD/ha	9	9	10	14
Harvest fodder	LD/m	0.1	0.1	0.1	0

†LD = Labour day

Table 5: *Investment costs for the three SWC measures in Kwalei*

Farmer	Investment costs		
	Bench terraces (US$)	*Fanya juu* (US$)	Grass strips (US$)
F28	339 (0)†	253 (0)	86 (0)
F20	358 (21)	264 (20)	118 (21)
F5	157 (0)	107 (0)	47 (0)
F2	352 (18)	256 (18)	97 (11)
F7	240 (8)	201 (14)	78 (13)
F8	144 (9)	108 (10)	49 (11)
F9	205 (67)	102 (7)	65 (14)
F11	207 (17)	150 (13)	65 (13)
F12	321 (0)	218 (0)	102 (0)

†Numbers in brackets are extra investment costs due to surface run-on

Strategies to overcome the high investment cost were stepwise construction of SWC measures, whereby a SWC measure is implemented on a portion of the field each season until the whole field is covered. Another alternative by farmers was to extend the existing labour sharing groups to SWC measures where they work together to construct SWC measures on each member's field. The results also show the additional costs to a farmer with fields on the down-slope part of a hill, because of the surface run-on from the upslope field.

Individual farmers experiencing the run-on effects proposed a meeting with upslope farmers to discuss these costs. Using these results it was possible to discuss with farmers the need for conservation of all fields in the catchment. Farmers realized this and they proposed several measures to ensure more adoption of soil conservation measures. The proposed solutions included awareness campaigns so that everyone realizes the effects of soil erosion and the need for SWC conservation. The village leaders through the SWC committee should supervise the implementation of SWC measures, and mobilize farmers to start small credit facilities where they can get financial loans. Farmers proposed that the central government through extension services should assist in training of more village technicians to layout the SWC measures. Moreover, the central government should ensure better markets for their crops.

Identification and quantification of benefits of SWC measures (Step 4)

The expected benefits from SWC measures were identified to be reductions of surface run-off and soil loss, and increased nutrient and moisture retention. These effects are expected to increase crop yields. Grasses on the risers are expected to improve fodder production for cattle, while farmers without cattle can sell the grass and increase their cash income. These benefits were also quantified and given monetary values.

Determination of the net benefits (Step 5)

The extension staff in collaboration with the researchers was able to use the financial analysis tool in comparing the costs and benefits of the current situation, hence realizing the net benefits over a five years period (cash flow) for each representative farmer. Results in Table 6 show the cash flow of the without soil conservation situation for five years. These results indicate that the majority of farmers are making losses because the production costs are higher than the benefits they are getting.

Table 6: *Cash flow over five years for the current situation without SWC measures for farmers with different biophysical and socio-economic conditions in Kwalei catchment, Tanzania.*

Farmer	Cash flow		
	Year 1 (US$)	Year 3 (US$)	Year 5 (US$)
F28	-46	-47	-47
F20	78	71	64
F5	-10	-11	-13
F2	-57	-58	-59
F7	-31	-32	-34
F8	-12	-13	-15
F9	58	53	51
F11	-46	-44	-42
F12	6	5	3

Only few farmers (F20, F9 & F12) are making net benefits in the current situation because of relative high yield levels, but there is a decreasing cash flow with time indicating that the benefits from the without conservation situation are not sustainable. This was discussed with the respective farmers and it became clear that there is a need for conservation even if the yield levels are relatively high. The results on the cash flow after implementing the respective soil conservation measures show a negative cash flow during the first year for the majority of farmers (Table 7). This is because during this initial period, the yield levels on SWC measures are not high enough to overcome the investment costs and compensate for the lost area.

According to farmers and field experiments (Tenge et al., 2004a) in some cases there is an initial yield decline especially for bench terraces because of the soil disturbances. The results are similar to the findings by Ekbom (1995) in Muranga district, Kenya, where the net benefits obtained for the first three years were the highest on fields without soil conservation measures. These results supported farmers' fear that SWC measures reduce crop yield and the cultivable area. However, through discussions farmers came to an agreement that this was only for a short term and should not be considered as a long-term problem.

Table 7: *Cash flow of three SWC measures over five years and for farmers withdifferent socio-economic and biophysical situation in Kwalei catchment, Tanzania.*

Farmer	Cash flow								
	Bench terraces (US $)			Fanya juu (US $)			Grass strips (US $)		
	Year 1	Year 3	Year 5	Year 1	Year 3	Year 5	Year 1	Year 3	Year 5
F28	-170	183	184	-151	95	100	-129	133	135
F20	-183	143	150	-182	47	53	-83	67	72
F5	-42	94	97	-10	53	59	-8	43	49
F2	-181	219	221	-159	108	114	-129	162	164
F7	-73	123	125	-70	106	108	-130	32	38
F8	4	57	60	10	48	51	13	14	19
F9	39	56	61	31	45	51	32	37	41
F11	-129	122	123	-120	107	110	-51	27	33
F12	-121	162	165	-117	129	132	-133	67	72

Table 8: *Financial benefits (NPV) of three SWC measures over the period of 15 years in Kwalei catchment, Tanzania.*

Farmer	NPV† at 8%		
	Bench terraces (US$)	Fanya juu (US$)	Grass strips (US$)
F28	598	313	294
F20	546	219	134
F5	328	293	192
F2	766	310	397
F7	640	216	207
F8	320	144	108
F9	215	205	78
F11	730	306	288
F12	567	321	153

† NPV = net present value

Long term benefits of SWC measures (Step 6)

Results on long-term benefits of SWC as indicated by the net present value, show that despite the high investment costs, bench terraces are more profitable than other SWC measures (Table 8). This is because of their effectiveness in reducing soil loss and in moisture retention, which gives a higher yield increase on fields with bench terraces than on fields with other SWC measures (Tenge et al., 2004a). However, the high investment costs limit farmers to adopt bench terraces.

Farm-level selection of SWC measures (Steps 7 and 8)
After discussion, the majority of farmers opted to establish grass strips as a first step towards establishment of *fanya juu*. The grass strip accumulates soil, and develops into a *fanya juu* terraces with time. Options to increase the benefits were also discussed, they included use of improved varieties, growing high value crops such as vegetables and banana and proper agronomic practices.

Conclusions

Results on the evaluation of the participatory soil erosion-mapping tool and financial analysis tool lead to the following conclusions. Farmers have a rich knowledge on indicators of soil erosion. Integration of this knowledge in SWC planning has a great potential to increase adoption of SWC measures, because it makes farmers participate and own the SWC plans. The soil erosion-mapping tool has demonstrated this potential by enabling farmers' participation in identification, mapping and planning of soil and water conservation. The use of the soil erosion-mapping tool made it possible not only to identify the soil erosion situation in the catchment, but also to locate the sources of surface runoff, leading to a SWC planning at both field and catchment scales.

The financial analysis tool made farmers translate the erosion symptoms (indicators) into financial losses, which increased awareness among them of the losses due to soil erosion and the benefits of soil and water conservation. This enabled them to select SWC options that were feasible to their physical and socio-economic conditions. In these ways the financial analysis tool demonstrated how the farmer can make an informed selection of SWC measures that are feasible under the given biophysical and socio-economic conditions. The financial analysis tool pinpointed the extra costs farmers incur because of surface run-on from upslope fields. These results also made farmers to give due consideration to run-on problems and discuss the need for SWC measures at the catchment level.

Unlike many other models and tools, the input data to the erosion mapping and financial analysis tools do not need complicated field measurements. This increases their potential to be used in areas with scarce scientific data but rich farmer's knowledge. Adoption of these tools could fill the gaps identified under the CA and therefore increase the acceptance of SWC measures. Firstly, they increase participation of farmers from the soil erosion problem identification to planning of SWC. During planning of SWC measures the two tools make farmers think of soil conservation at both farm and catchment levels. Secondly, they enable farmers to understand the financial benefits of SWC measures before the implementation. In this way, they make an informed decision to select feasible SWC measures.

Despite the potential of the financial analysis tool to increase participation of farmers in planning of SWC measures and hence raise adoption, the following limitations should be considered. The tool may underestimate the benefits of soil conservation as it considers only benefits that can be translated into financial terms. There may be other economic gains that are not translated into financial terms. Moreover, the results from the erosion mapping and financial analysis tools should be considered together with factors other than financial benefits, e.g. cultural and religious values, which farmers may need to consider before deciding to implement certain soil and water conservation measures. Further evaluation of the tools under different biophysical and socio-economic conditions is recommended to increase their geographical applicability.

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Chapter 7

CONCLUSIONS

Conclusions

This chapter begins by recapitulating the rationale behind the research. Then the conclusions derived during this research are restated and discussed.

The problem and the approach

In the past, efforts in soil and water conservation (SWC) in the West Usambara highlands of Tanzania have not been successful, i.e. there has been low farmer adoption of proposed SWC measures. Many authors attribute this to a top–down approach that neglected farmers' knowledge and their participation in planning and failed to consider the financial implications of the proposed SWC measures at the planning stage. However, to put the blame on this seems to be too easy, because for over two decades the main institution used to implement SWC has been the so-called catchment approach (CA). The basic principle underlying the CA is the participation of all stakeholders in the planning of SWC. In the CA, a multidisciplinary team of professionals, farmers and other stakeholders are involved in participatory appraisal in which different constraints are identified and ranked in order of priority. The time allocated to improve a particular catchment is up to two years. So why, in spite of due attention to participation, is adoption still so low?

It will be recalled that the problem with the current CA approach is that because the nature of soil erosion and its related problems may take a long time to be observed, only in rare cases do soil erosion and conservation rank high among the priority problems in participatory rural appraisal meetings. Also, the time set to address soil erosion and conservation in a particular catchment is too short to observe the effects. As a result, successes of the CA for SWC have been observed only in areas where the community already knew the problems of soil erosion, could visualize the benefits of soil conservation and were willing to participate.

In addition to a problem with the temporal aspect there is also a problem with the true participation of farmers. As discussed in chapter 2, three shortcomings have been identified. First, the extent and quality of the involvement of the communities is not encouraging; agricultural extension officers are still leading the community too much on the basis of their own experiences and their own criteria. Secondly, often the quantification of the actual soil and water loss is not carried out, hence the demonstration effects of soil erosion and benefits of conservation are not observed and therefore do not convince farmers to invest in SWC. The third shortcoming of CA is that the economics of soil and water conservation often do not play a role in the planning of soil conservation measures, with the result that farmers do not realize the costs and benefits of SWC measures before these are implemented. Translating the losses by erosion and the benefits of soil and water conservation measures into financial terms would motivate farmers, policy makers and other actors to invest more in soil erosion control measures.

The aim of the EROAHI research project was to improve the performance and impact (i.e. more adoption) of the CA approach by developing two tools for an improved planning of SWC measures: a tool for participatory soil erosion mapping, and a tool for the participatory appraisal of SWC measures. The development of the latter tool was the subject of the research described in this thesis. This tool was to be developed together with the farmers, in order to adequately consider their perception about and assessment of the effectiveness and financial efficiency of the SWC measures. Both tools were extensively tested in the two research areas.

Are there SWC measures attractive for farmers?

A farm survey (chapter 2) showed three major soil and water conservation measures were being used in the West Usambara highlands: bench terraces, *fanya juu* (ditch and bund along the contour) and grass strips. The farmers' reasons for these preferences were based on many other factors besides the physical effectiveness. Among the criteria were short-term benefits and costs of implementing the SWC measures.

The farmers' knowledge was compared with scientific evidence. In experiments conducted over a two-year period (chapter 3), the three SWC measures were evaluated in terms of their effectiveness in reducing soil loss and surface runoff, retaining soil moisture, and their impacts on maize and bean yields. *Fanya juu* reduced soil and water losses most effectively, while bench terraces retained more soil moisture and increased crop yields more than the other measures. Grass strips were the least effective for soil and water conservation purposes. It was concluded that the proposed SWC measures are physically effective if implemented and maintained according to the recommendations.

The question remains whether these effective measures are also affordable. A financial cost-benefit analysis (FCBA) revealed that on average the costs of installing SWC measures were respectively US\$ 215 ha^{-1} for bench terraces, US\$ 165 ha^{-1} for *fanya juu* and US\$ 84 ha^{-1} for grass strips. These costs increased with an increase in slope steepness and opportunity costs of labour. The costs also depended on the stability of the soil, being higher on an unstable soil than on stable soil. The results also showed that it takes at least two years before a farmer can realize a positive cash flow. The long-term benefits expressed as net present value at 8% discount rate were US \$ 608 ha^{-1} for bench terraces, US \$ 309 ha^{-1} for *fanya juu* and US \$184 ha^{-1} for grass strips.

Whereas these SWC measures seem financially attractive, there are usually many other factors determining whether or not farmers will adopt the measures.

The research described in chapter 2 has shown that adoption of SWC measures was positively influenced by membership of farmer groups, level of education, contacts with extension agents and participation in SWC programmes. Factors that negatively influenced adoption of SWC measures were involvement in off-farm activities, insecure land tenure, location of fields and a lack of short-term benefits from SWC.

The overall conclusion after the extensive consultations with farmers and scientific experimentation is that, depending on the circumstances, there are SWC measures that are attractive to farmers. However, for these to be adopted, there are a number of prerequisites:

1. More awareness among farmers of soil erosion effects and of the long-term benefits of SWC;
2. A choice of SWC measures that cater for different farmer objectives and circumstances;
3. Awareness of the costs and benefits of SWC;
4. Improved participation of farmers in SWC planning.

How to improve the CA approach?

A major finding of this research is that farmers have their own objectives for land and water management and thus their own criteria to evaluate SWC measures, depending on their socio-economic conditions. Having concluded this, one could follow two trails. One is to refine existing deterministic (scientific) planning tools by incorporating proxies for all socio-economic conditions that are considered drivers for planning. This trail was rejected because it would be too costly to acquire the data required. Instead another – innovative – trail was followed. Two farmers' tools were developed that can be simply and cheaply applied by the farmers themselves. This allows farmers to make tailor-made choices that suit their different individual objectives. Farmers experience more freedom, and feel they are taken more seriously and respected.

The scientific research described in chapter 4 showed that there are SWC measures that are attractive for farmers but that a number of prerequisites need to be fulfilled in order to facilitate their adoption. These prerequisites were synthesized into two concrete "design actions":

1. A new method of farmers' participation that overcomes the present problems in the CA approach, called the "erosion mapping tool" and
2. A tool for farmers to estimate the financial costs and benefits of SWC measures before they are implemented under different biophysical and socio-economic situations of farmers, called the "financial tool".

The new "erosion-mapping tool" makes use of farmers' indicators of soil erosion. Using these indicators facilitated farmers' participation in the identification, classification and mapping of soil erosion problems at field and catchment levels. The use of this soil erosion-mapping tool made farmers participate in the identification of soil erosion problems and in the planning of SWC. Severely eroded areas were identified and corresponding remedial measures discussed. During the participative planning process that followed the identification, classification and mapping, farmers became well informed and participated in the planning of SWC at both field and catchment levels by selecting SWC measures that were feasible under their social and economic conditions.

In the newly developed "financial tool" the physical effectiveness of the alternative SWC measures was integrated into the tool by means of the estimated yield increases. The financial analysis tool enabled farmers to translate the erosion symptoms and the benefits of conservation into financial terms: this increased the farmers' awareness of the effects of soil erosion and the costs and benefits of conservation measures. Individual farmers selected SWC options that were physically effective and financially feasible under their physical and socio-economic conditions.

The two tools helped farmers to give due consideration to and discuss the need for SWC planning at the catchment level. Further evaluation of the tools is recommended to increase their geographical applicability. In order to facilitate this further evaluation and eventual use of the tools, a detailed explanation on how a participatory appraisal can be carried out with the financial analysis tool is given as an annex to this thesis.

Institutional and policy implications

Although SWC measures seem attractive at first glance, it was concluded (chapter 4) that the high investment costs and initial negative returns constrain adoption of SWC measures. Options to overcome the investment costs include stepwise construction of SWC measures, labour-sharing groups and growing high value crops. The extension staff should advocate these options. It was also found that SWC measures are not financially attractive to most farmers with off-farm employment and income, because of their higher opportunity cost of labour. For these farmers a change towards crops with high gross margins per manday could be a precondition for the implementation of SWC measures.

A more effective agricultural extension system should help raise awareness of the benefits of SWC and promote these SWC measures. Within the Catchment Approach, extension staff in collaboration with farmers and other stakeholders should from now on work on implementing and refining both participatory tools. Since the involvement of farmers in the financial analysis will help them realize the costs of soil erosion and the long-term benefits of soil conservation, farmers will make better decisions with regard to soil and water conservation.

In chapter 5 some attention was paid to the possibility of using multi criteria analysis (MCA) instead of financial cost-benefit analysis (CBA). This would allow for the integration of several other criteria that farmers found important and that would otherwise not have been considered. Besides it would enable an analysis from the point of view of different stakeholders. The MCA method showed a similar ranking of SWC alternatives for farmers and for government agencies. This was, among other things, attributed to the non-conflicting objectives between farmers and government agents; this conclusion is important, since it means that the local institutional and policy setting is in line with farmers' development objectives. However, because of the many subjective elements in MCA and some other shortcomings, in the end this method was not incorporated in the tool.

While the SWC measures recommended by the extension service in West Usambara highlands seem to be financially efficient in the long term, their investment costs are often too high for farmers and the financial benefits take too long to appear. In order to support the efforts by individual farmers and extension staff, there is therefore a need for several policy interventions. These should ensure the availability of credit schemes for investment in SWC, promote more secure land tenure systems for farmers to assure them of the long-term benefits of SWC, and improve market access so farmers can sell their produce at reasonable prices.

The enthusiastic participation of farmers and other stakeholders in the development and application of the participatory appraisal tool could be considered as an encouraging sign for the future use of this tool in SWC planning.

Chapter 8

SUMMARY

Summary

Soil and water conservation (SWC) measures are needed to control soil erosion and sustain agricultural production on the steep slopes of Usambara Mountains. The need for SWC has resulted in the development and promotion of several SWC measures by both governmental and non-governmental programmes. However, there is limited information on their physical effectiveness and financial efficiency to convince farmers to invest in SWC. Furthermore, farmers' preferences and the socio-economic factors that influence the adoption of SWC measures have not been adequately considered. As a result, the adoption of many recommended SWC measures is minimal and soil erosion continues to be a problem.

This research explored the socio-economic reasons for low adoption of SWC measures in the West Usambara highlands in Tanzania. The research generated both biophysical and socio-economic information that was used to improve the current SWC planning approach. Major SWC measures used in the West Usambara highlands were then appraised using the improved participatory approaches that integrated the physical effectiveness and financial efficiency of the SWC measures and other socio-economic factors of the land users.

Chapter 2: Social and economic factors affecting the adoption of soil and water conservation in West Usambara highlands, Tanzania

The research started by investigating the social and economic factors that influence farmers' decisions to undertake certain soil and water conservation measures. Household surveys and group discussions with different categories of farmers were used to collect the social and economic data. A total of 104 households were interviewed and numerous fields visited. Data were analysed using both participatory methods and statistical procedures. The results indicate that the major factors that negatively influence adoption of SWC measures are involvement in off-farm activities, insecure land tenure, location of fields and a lack of short-term benefits from SWC. Membership in farmer groups, level of education, contacts with extension agents and SWC programs were found to positively influence the adoption of SWC measures. It is concluded that in order to facilitate adoption of SWC measures there is a need for the integration of social and economic factors into SWC plans, and for the creation of more awareness among farmers of soil erosion effects and of the long-term benefits of SWC. Participatory development of flexible SWC options that cater for different farmer objectives is also needed. However, in order to increase farmers' awareness on the effects of soil erosion and the benefits of soil and water conservation, farmers need more information. And tools for the adequate participation of farmers in SWC planning appear to be lacking.

Chapter 3: Physical effectiveness of and farmers' preferences for soil and water conservation measures in the East African highlands

In order to understand whether the recommended soil and water conservation measures are in fact effective in reducing soil erosion and match with farmers' preferences, field experiments were conducted to assess the effectiveness of bench terraces, *fanya juu* (see footnote in Chapter 2) and grass strips. These were identified as the major soil and water conservation measures in the West Usambara highlands. The assessment was undertaken with the use of Gerlach troughs and natural

erosion plots replicated four times. In these experiments conducted over a two-year period, the three SWC measures were evaluated in terms of their effectiveness in reducing soil loss and surface runoff, retaining soil moisture, and their impacts on maize and beans yields. Farmers also assessed these SWC measures by matrix ranking based on their criteria for preferences and performance of the measures in field experiments. The results indicated that SWC measures reduced annual soil loss from 25 t ha^{-1} on fields without SWC to 15 t ha^{-1} between grass strips, 6 t ha^{-1} on bench terraces and 3 t ha^{-1} on *fanya juu*. Surface runoff was reduced by 74 % on *fanya juu*, 49 % on bench terraces and 25 % between grass strips. Bench terraces increased maize yield by 88 %, *fanya juu* by 57 % and grass strips by 14 %, with reference to the yield level in the situation without measures. The increase in bean yield due to SWC measures was 60 % on bench terraces, 67 % on *fanya juu* and 13 % between grass strips, also with reference to the situation without measures. Farmers' reasons for preferences for certain soil and water conservation were based on many other factors besides the physical effectiveness. Short-term benefits and costs of implementing the SWC measures were among the criteria. Ranking of the three SWC measures according to farmers' criteria was as follows: bench terraces, *fanya juu* and grass strips. It was concluded that the proposed SWC measures are physically effective if implemented and maintained according to the recommendations, and for appropriate soil and slope conditions.

Chapter 4: The financial efficiency of major soil and water conservation measures in West Usambara highlands, Tanzania

A Financial Cost-Benefit Analysis (FCBA) was performed to assess the financial efficiency of bench terraces, *fanya juu* and grass strips in comparison with the "without conservation situation". The analysis focused on the most common cultivation of maize and beans. The FCBA was performed for three groups of farmers under different socio-economic and biophysical situations. These farmer groups were distinguished on the basis of household characteristics such as sex, age, education level, family composition and also on the basis of resource availability and use, such as farm size, type of crops and livestock, involvement in off-farm activities and sources and type of labour. The three groups of farmers had respective labour opportunity costs of 80 %, 100 % and 120 % of the daily wage rate applicable in the research area. FCBA results revealed that on average the costs of installing SWC measures were respectively US $ 215 ha^{-1} for bench terraces, US $ 165 ha^{-1} for *fanya juu* and US $ 84 ha^{-1} for grass strips. These costs increased with an increase in slope steepness and opportunity costs of labour. The costs also depended on the stability of the soil, being higher on an unstable soil than on stable soil. The results also showed that it takes at least two seasons before a farmer can realize a positive cash flow. The long-term benefits expressed as net present value at 8% discount rate were US $ 608 ha^{-1} for bench terraces, US $ 309 ha^{-1} for *fanya juu* and US $184 ha^{-1} for grass strips. It was also found that SWC measures are not financially attractive to most farmers with off-farm employment and income, because of their higher opportunity cost of labour. It was concluded that the high investment costs and initial negative returns are the major constraints to the adoption of SWC measures. Options to overcome the investment costs include stepwise construction of SWC measures, labour sharing groups and growing high value crops.

Chapter 5: Application of multi-criteria analysis in soil and water conservation: case study of West Usambara highlands.

A participatory appraisal of the three SWC measures was performed using Multi-Criteria Analysis (MCA). The appraisal was based on three physical effectiveness criteria (Chapter 3), five financial efficiency criteria (Chapter 4) and four other criteria for the evaluation of SWC measures, as set by farmers and government agents as the main stakeholders. The three SWC measures were evaluated and ranked in a participatory way according to the MCA procedures. The MCA approach revealed the following: firstly it provided room for both farmers and government agents to interact and participate in defining the objectives and criteria to evaluate SWC measures. Secondly, through the use of MCA it was possible to incorporate many criteria in the evaluation that had previously not been considered. Thirdly, the criteria were by themselves important in identifying aspects to be considered in the design and planning of SWC. The ranking of SWC alternatives turned out to be similar for farmers and the government agencies. This was attributed to the non-conflicting objectives between farmers and government agents, and also to the compensation effects of the weighted summation method used in MCA. Despite the advantages of the MCA analysis the following shortcomings were observed: firstly, the qualitative assessment of the impacts of the alternatives on the criteria was subjective, depending on the perception by the farmers. This necessitated the use of physical research data that were very costly to obtain. It was concluded that where there is a big gap in knowledge on the effects of alternatives on the criteria, MCA is more useful in the participatory exploration of the land actors' viewpoints rather than in the ranking of alternatives. Secondly it is difficult to incorporate the time dimension in MCA, and with SWC measures there is usually a large time lag between costs and benefits.

While MCA made it possible to include both effectiveness and efficiency criteria, the effectiveness should and is, at least partly, also reflected in the efficiency (in FCBA). For that reason it was decided to use only financial cost-benefit analysis in the tool for the appraisal of SWC measures (Chapter 6 and Annex).

Chapter 6: Application of soil erosion mapping and financial analysis tools in soil and water conservation planning: case study of Kwalei catchment in West Usambara highlands, Tanzania

Two participatory tools for SWC planning were developed and evaluated. The first tool uses farmers' knowledge of erosion indicators to identify, classify and map eroded fields in the catchments. The second tool analyses the financial costs and benefits of SWC measures before they are implemented under different biophysical and socio-economic situations of farmers. The physical effectiveness was integrated into the financial analysis tool by means of the yield increases. The use of the soil erosion mapping tool made farmers participate in the identification of soil erosion problems and in the planning of SWC. Severely eroded areas were identified and corresponding remedial measures discussed. The financial analysis tool enabled farmers to translate the erosion symptoms and the benefits of conservation into financial terms: this increased farmers' awareness of the effects of soil erosion and the costs and benefits of conservation measures. Individual farmers selected SWC options that were physically effective and financially feasible under their physical and socio-economic conditions. The two tools also helped farmers to give due consideration to and discuss the need for SWC planning at the catchment level. Further evaluation of the tools is recommended to increase their geographical applicability. In order to facilitate this further evaluation and eventual use of the tools, a detailed explanation on how a participatory appraisal can be carried out using the financial analysis tool is given as an annex.

Chapter 7: Conclusions

A participatory appraisal tool for SWC planning at farm and catchment levels has been developed. To achieve this, physical effectiveness and financial efficiency of major SWC measures used in the West Usambara highlands were evaluated by detailed physical research (field experiments) and household surveys. The results were then used to develop the financial analysis tool for appraisal of SWC measures, as described in detail in the annex. The results of this research have contributed to the EROAHI objectives of improving the catchment approach by quantifying the effects of soil erosion and assessing the financial returns of SWC measures. The use of the erosion mapping and financial analysis tools has increased farmers' participation in SWC planning.

Samenvatting

Op de steile hellingen van het Usambara gebergte zijn bodem- en waterconserverings (BWC)-maatregelen nodig om erosie tegen te gaan en om landbouw te kunnen bedrijven. Deze noodzaak tot BWC heeft geleid tot de ontwikkeling en uitvoering van verschillende BWC maatregeleen door zowel gouvernementele als niet-gouvernementele organisaties. Echter, er is beperkte informatie beschikbaar over de fysische effectiviteit en de financiële efficiëntie van de maatregelen. Deze informatie zou kunnen helpen bij het overtuigen van boeren om in BWC te investeren. Voorkeuren van boeren en sociaal-economische factoren die een rol spelen bij de adoptie van BWC maatregelen zijn tot nu toe onvoldoende in beschouwing genomen. Als gevolg hiervan is de adoptie van veel aanbevolen BWC maatregelen minimaal en erosie blijft dan ook een probleem.

Deze studie onderzoekt de sociaal-economische oorzaken van een lage adoptie van BWC maatregelen in de West Usambara hooglanden van Tanzania. Het onderzoek richtte zich op zowel bio-fysische als sociaal-economische factoren die een rol spelen bij de huidige BWC planning. De belangrijkste BWC maatregelen die in de Usambara hooglanden worden gebruikt zijn geëvalueerd met behulp van een verbeterde participatieve aanpak, welke fysisch effecten, financiële efficiëntie en andere sociaal-economische factoren van de landgebruikers integreert.

Hoofdstuk 2: Sociale en economische factoren die de adoptie van bodem en waterconservering beïnvloeden in de West Usambara hooglanden, Tanzania

Het onderzoek is gestart met een studie naar de sociale en economische factoren die van invloed zijn op de beslissing van boeren om bodem- en waterconserveringsmaatregelen te nemen. Gegevens werden verzameld door een huishoudonderzoek en door middel van groepsdiscussies met verschillende categorieën boeren. De data werden geanalyseerd door middel van zowel participatieve- als statistische methoden. De belangrijkste factoren die de adoptie van maatregelen negatief beïnvloeden zijn betrokkenheid bij niet-landbouw activiteiten, onzekerheid over land eigendom, locatie van de velden en het gebrek aan korte termijn profijt van de maatregel. Lidmaatschap van boerengroepen, opleidingsniveau en contact met voorlichters en BWC programma's bleken factoren die de adoptie van de maatregelen positief beïnvloeden.

Om de adoptie van BWC maatregelen te vergemakkelijken is het nodig dat de sociale en economische factoren geïntegreerd worden in de BWC plannen en dat boeren bewust gemaakt worden van de gevolgen van erosie én van de effecten van de maatregelen. De (participatieve) ontwikkeling van flexibele BWC opties voor verschillende doelstellingen van de boeren is ook noodzakelijk.

Om de boeren bewust te maken van de gevolgen van erosie en de effecten van de maatregelen is meer informatie voor de boeren nodig. Methoden voor een adequate participatie van boeren in BWC bleken echter niet beschikbaar te zijn.

Hoofdstuk 3: Fysische effectiviteit van en de voorkeur van boeren voor bodem- en waterconserveringsmaatregelen in de Oost Afrikaanse hooglanden

Om te kunnen beoordelen of de aanbevolen BWC maatregelen effectief de erosie reduceren en of ze overeenkomen met de voorkeur van boeren is een veldexperiment uitgevoerd met bank terrassen, *fanya juu* (geul en dijkje langs hoogtelijn) en grasstroken. De genoemde maatregelen zijn geïdentificeerd als de belangrijkste BWC maatregelen in de West Usambara hooglanden. Het veldexperiment is uitgevoerde met Gerlach-troggen en op natuurlijke erosie plots (4 herhalingen) over een periode van twee jaar. De drie BWC maatregelen werden geëvalueerd op hun effectiviteit in het reduceren van bodemverlies en oppervlakte afstroming, het vasthouden van bodemvocht en op hun effect op de oogst van maïs en bonen. Ook de boeren maakten een beoordeling van de maatregelen door middel van een ordening op basis van hun eigen criteria voor voorkeur en doeltreffendheid van de maatregel.

De resultaten tonen dat BWC maatregelen het jaarlijkse bodemverlies verminderen van 25 t ha^{-1} op velden zonder BWC tot 15 t ha^{-1} tussen grasstroken, 6 t ha^{-1} op bankterrassen en 3 t ha^{-1} op *fanya juu*. Oppervlakte afstroming werd gereduceerd met 74% op *fanya juu*, 49% op bankterrassen en 25% tussen grasstroken. De maïsoogst vermeerderde ten opzichte van de situatie zonder maatregel met 88% op bankterrassen, 67% op *fanya juu* en met 14% tussen grasstroken. De opbrengst vermeerdering van bonen als gevolg van de BWC maatregelen was 60% op bankterrassen, 67% op *fanya juu* en 13% tussen grasstroken.

De redenen die boeren aangeven voor hun voorkeur voor een bepaalde maatregel zijn gebaseerd op vele andere dan fysische factoren. De voorkeur van de boeren volgens hun eigen criteria is in afnemende volgorde: bankterrassen, *fanya juu* en grasstroken.

De voorgestelde maatregelen zijn fysisch effectief wanneer deze geïmplementeerd zijn en onderhouden worden volgens de technische instructies en op de geschikte bodem en helling.

Hoofdstuk 4: De financiële efficiëntie van de belangrijkste bodem- en waterconserveringsmaatregelen in de West Usambara hooglanden, Tanzania

Om de financiële efficiëntie van de bankterrassen, *fanya juu* en de grasstroken te beoordelen is een Financiële Kosten-Baten Analyse (FCBA) uitgevoerd. In de analyse is uitgegaan van de verbouw van maïs en bonen. De studie werd uitgevoerd onder drie groepen boeren onder verschillende sociaal-economische en bio-fysische omstandigheden. De groepen werden onderscheiden op basis van de karakteristieken van het huishouden, b.v. gender, leeftijd, opleidingsniveau, familiesamenstelling, en op basis van de beschikbare hulpbronnen, b.v. oppervlakte van het bedrijf, gewastypen, veestapel, betrokkenheid bij niet-landbouw activiteiten en de beschikbaarheid van arbeid. De driegroepen hadden respectievelijk kosten van arbeid in alternatieve aanwending van 80%, 100% en 120% van het dagelijkse loonniveau in het onderzoeksgebied.

Uit de FCBA blijkt dat de gemiddelde kosten voor de aanleg van bankterrassen US$215 ha^{-1} bedroegen, US$165 ha^{-1} voor *fanya juu* en US$85 ha^{-1} voor grasstroken. De kosten worden hoger bij toenemende helling en hogere kosten van arbeid in alternatieve aanwending. De kosten hangen eveneens af van de stabiliteit van de bodem, met hogere kosten voor instabielere bodems.

Uit de FCBA blijkt ook dat het minstens twee seizoenen duurt voordat een boer een positief financieel resultaat kan behalen van de maatregelen. Het profijt op lange termijn, uitgedrukt als netto huidige waarde met 8% aftrek was US$608 ha^{-1} voor bankterrassen, US$309 ha^{-1} voor *fanya juu* en US$184 ha^{-1} voor grasstroken.

BWC maatregelen blijken niet financieel aantrekkelijk te zijn voor boeren met een (additioneel) inkomen van buiten de landbouw, omdat deze hogere kosten van arbeid in alternatieve aanwending hebben. De adoptie van BWC maatregelen wordt beperkt door hoge investeringskosten en de initiële negatieve opbrengsten. Mogelijkheden om deze bezwaren op te heffen bestaan uit de geleidelijke constructie van de BWC maatregel, het creëren van samenwerkingsverbanden bij de aanleg en de verbouw van hoogwaardige gewassen.

Hoofdstuk 5: De toepassing van multi-criteria analyse: een case studie in de West Usambara hooglanden

Door middel van multi-criteria analyse is een participatieve beoordeling van drie BWC maatregelen uitgevoerd. De beoordeling is gebaseerd op de drie criteria voor fysische effectiviteit (hoofdstuk 3), de vijf criteria voor de financiële efficiëntie (hoofdstuk 4) en vier andere criteria voor de evaluatie van BWC maatregelen. De vier laatste zijn vastgesteld door de belangrijkste belangengroepen: de boeren en de overheidsinstanties.

De drie BWC maatregelen zijn op participatieve wijze en volgens de MCA procedure geëvalueerd en gerangschikt naar voorkeur. De genoemde aanpak maakt het mogelijk, voor zowel de boeren als de overheid, om bij te dragen aan de definiëring van de doelstellingen en de evaluatiecriteria van de maatregelen. Ook was het door de MCA aanpak mogelijk om meer criteria in de evaluatie te betrekken dan tot dan toe werd gedaan. Als laatste werd duidelijk dat de gedefinieerde criteria van belang zijn bij de identificatie van aspecten die bij het ontwerpen en plannen van BWC maatregelen in beschouwing moeten worden genomen.

De boeren en overheidsinstanties gaven een zelfde voorkeur aan voor de BWC maatregelen. Dit komt door het ontbreken van conflicterende doelstellingen tussen de boeren en de overheid, maar ook door het compenserende effect van de gewogen gemiddelde methode die in de MCA gebruikt werd. Ondanks de voordelen van de MCA werd een aantal tekortkomingen geconstateerd; ten eerste hing de kwalitatieve beoordeling van het effect van de maatregel op de criteria af van de (subjectieve) perceptie van de boeren. Hierdoor was het nodig om fysische onderzoeksgegevens te verzamelen, hetgeen erg kostbaar was. Als het verschil tussen perceptie en werkelijkheid t.a.v. de effecten van de alternatieven op de criteria groot is, is MCA geschikter voor het beschrijven van het standpunt van de boeren dan voor het aangeven van voorkeuren. Ten tweede is het moeilijk een tijdsdimensie in te brengen in MCA terwijl bij BWC maatregelen er in de regel een groot tijdsverloop zit tussen kosten en baten. Alhoewel het in MCA mogelijk is om zowel effectiviteit als efficiëntie in te bouwen moet de effectiviteit ook gereflecteerd worden in de efficiëntie (in FCBA), en voor een deel is dat ook zo. Daarom is besloten slechts gebruik te maken van FCBA bij het beoordelen van BWC maatregelen (hoofdstuk 6 en annex).

Hoofdstuk 6: De toepassing van erosiekaarten en methoden voor een financiële analyse bij BWC planning: case studie van het Kwalei stroomgebeid in de West Usambara hooglanden, Tanzania

Er zijn twee methoden voor BWC planning ontwikkeld en geëvalueerd. Het eerste gebruikt de kennis van boeren over erosie om geërodeerde velden in het stroomgebied te identificeren, te classificeren en in kaart te brengen. Het tweede analyseert de kosten en baten van BWC maatregelen onder verschillende bio-fysische en sociaal-economische omstandigheden. De fysische effectiviteit is geïntegreerd in de financiële analyse, door middel van een toename in de oogst.

Boeren participeren in het proces van identificatie van erosie problemen en in de planning van BWC door middel van het maken van erosiekaarten. Geërodeerde gebieden werden geïdentificeerd en de bijbehorende maatregel bediscussieerd. De financiële analyse maakte het de boeren mogelijk om de erosie en de maatregelen te vertalen in financiële termen, waardoor de boeren zich bewuster werden van de effecten van erosie en van de kosten en baten van de maatregel. Individuele boeren selecteerden een BWC maatregel die onder hun omstandigheid fysisch effectief en financieel haalbaar waren.

De twee genoemde methoden zijn bedoeld om bewustwording te krijgen over de noodzaak van BWC op stroomgebiedniveau en om dit te bediscussiëren. Om de toepasbaarheid van de twee methoden uit te breiden naar andere geografische regio's is verdere studie noodzakelijk. Hiertoe is in de annex een uitgebreide en gedetailleerde uitleg gegeven van de participatieve beoordelingsmethode met behulp van de financiële analyse.

Hoofdstuk 7: Conclusies

Er is een participatieve beoordelingsmethode voor BWC planning op bedrijfs- en stroomgebiedsniveau ontwikkeld. Om dit te bereiken werden de fysische effectiviteit en de financiële efficiëntie van de in de West Usambara hooglanden meest toegepaste BWC maatregelen geevalueerd door middel van veldonderzoek en onderzoek onder de boeren huishoudens.

De resultaten van dit onderzoek zijn gebruikt om een methode voor financiële analyse te ontwikkelen (beschreven in de annex). De resultaten van het onderzoek hebben een bijdrage geleverd aan de EROAHI doelstelling van het verbeteren van de Stroomgebied Aanpak door de gevolgen van erosie te kwantificeren en de financiële kosten en baten van de BWC maatregelen vast te stellen. Het gebruik van erosiekaarten en van de financiële analyse methode hebben de participatie van de boeren in BWC planning verbeterd.

ANNEX

TOOL FOR PARTICIPATORY FINANCIAL ANALYSIS OF SOIL AND WATER CONSERVATION MEASURES FOR FARM LEVEL PLANNING

Tool for participatory financial analysis of soil and water conservation measures for farm-level planning - Manual

Introduction

This manual gives a brief overview of a simple tool developed to analyse, together with farmers, the costs and benefits of different soil and water conservation measures under different situations of farms and farmers in the East African highlands. The tool forms part of a planning procedure, which has been developed in order to improve the Catchment Approach (CA), and includes among others another tool for the mapping of soil erosion (Okoba et al., 2005)

Objectives

The purpose of this tool is to assess the financial returns of SWC measures at the planning stage, both in the short and long runs. The tool was developed for the individual farm level, but can also include extra costs due to run-on effects. With the tool, a quick assessment of the costs and benefits over-time of different SWC-measures can be carried out. This means that before implementation of certain measures, the financial effects can be calculated for different types of farmers under certain agro-ecological situations and specific cropping systems. The tool will assist in identifying major components that can affect the costs and benefits of a given conservation measure, in comparing different alternatives, factors that are likely to give (more) benefits and the timeframe, within which benefits are realised. .

The participatory appraisal tool

The tool is in a form of a manual with instructions and spreadsheets and uses the basic principles of financial cost-benefit analysis (Enters, 1988; Kuyvenhoven and Mennes, 1989; de Graaff, 1996). In this analysis, both socio-economic and biophysical data are required. Socio-economic data are farm household characteristics (on the basis of which farmer groups are distinguished), input and output prices, the amount of labour and materials required for each operation to establish, produce and maintain each SWC measure and the opportunity costs of labour. Biophysical data include soil type, slope, erosion situation, type of crops, farm location and size, yield levels, available SWC options and their impacts on crop yields. The tool is used in a stepwise approach whereby all the costs to be incurred in implementing SWC measures are identified and quantified. Benefits that are expected from SWC measures are also identified and quantified. The financial benefits are then determined by comparing the stream of benefits and costs over a number of years depending on farmers' time preferences and the life span of the respective SWC measure. When the benefits outweigh the costs, the respective SWC measure is financially profitable. The manual consists of a number of instructions for the respective eight (8) steps of the tool and these are accompanied by several forms. These steps are shown in figure A1**.** The tool can be applied without the use of a computer, but if available, it can simplify its application and enable a fast analysis of different situations. However, the use of computer should not replace the participatory aspect of the tool.

The organisation of participatory appraisal of SWC

The financial analysis tool is intended to be used by agricultural extension staff working with farmers in rural areas. Professionals interested in financial analysis of SWC measures can also use this tool. A few farmers can also be trained and lead others in the steps of applying the tool. The training of these farmers can form part of the current training of village technicians under the Catchment Approach (CA). Researchers will be responsible for any training related to the financial analysis tool. The use of the financial analysis tool assumes that the area that needs conservation has been identified and that the initial PRA to collect baseline data has been conducted during other steps for the catchment approach in SWC planning (Kiara et al., 1999; Kizuguto and Shelukindo, 2003). In addition, it assumes that soil erosion problems and the need for soil conservation in the selected area have been identified using another tool for the participatory soil erosion mapping (Okoba et al., 2005). However, the following preparations are needed: The extension staff has to review and be aware of the baseline information of the area as collected during the PRA. Information relevant for application of the tool is the prevailing wage rate, off-farm activities, input and output prices and SWC options and their impacts. The extension staff has to contact local leaders and make an appointment with farmers whose fields need conservation, agree on the place and appropriate time for the visit or meeting. An extension officer who is not yet familiar with the physical environment of the area should work closely with the village technicians and the key informants. Village technicians are farmers who have been trained under CA on basic principles of SWC measures. Key informants are representative farmers, who are selected during the application of the soil erosion mapping tool on the basis of their knowledge of the catchment. If necessary, a pre-meeting can be arranged with the help of local leaders to meet the key informants and verify or update some information from the PRA. During the visit or meeting with farmers, the extension staff explains the objectives and expected outputs by showing to the farmers some examples such as a cash flow (Figure A8). The objective of the meeting is to identify and discuss with farmers the costs and benefits of SWC measures. The expected outputs would be the financial benefits of SWC measures selected by farmers and the costs that are to be incurred before these benefits are realized.

Application of the financial analysis tool

This tool is to be applied to one field at a time, but can be used with a single farmer or group of farmers if they share the same field. The extension staff or whoever applies the tool (lead person) should follow the steps shown in Figure A1 and described hereunder. During each step, the extension staff or lead person records the observations and responses in a pre-designed recording form (Tables A2-A5). The recording forms can be modified to suit the local conditions.

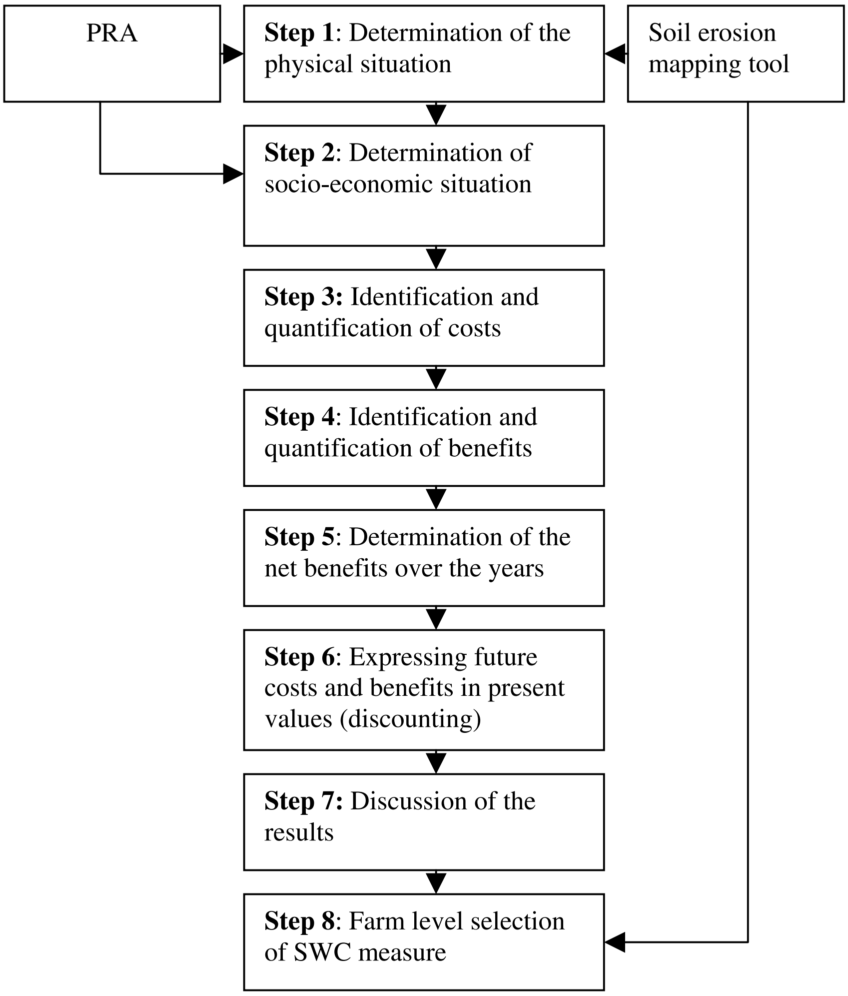

Figure A1. *Steps in the tool for financial analysis of soil and water conservation measures*

Step 1: Determination of biophysical situation

Aim: Identify the physical characteristics of the field (s) to be conserved.

Expected output**:** List of bio-physical situation (slope, field size, erosion class, soil, crops and yield levels) and SWC options for the respective field(s).

Activities

With the help of the soil erosion map from the participatory soil erosion mapping tool (Okoba et al., 2005), farmers locate their fields, identify the physical situation of slope, erosion class, crops, and yield levels (Figures A2 and A3). Village technicians will help farmers to identify biophysical conditions that are not directly observed from the erosion map such as slope percentages and soil stability. Based on the biophysical situation of the fields and the land use intended by farmers, the extension staff leads the discussion and selection of SWC options for the respective fields and land use (Table A1). Options from farmers are also included in the discussion. If a field receives run-on from upslope, an infiltration ditch or cut-off drain is needed and therefore added to the list of SWC options. The financial analysis tool compares the benefits of SWC with reference to the without conservation situation, therefore the without conservation situation is also included in the list of SWC options selected by farmer(s).

- After the discussion, the extension staff or any lead person fills the collected information inTable A2, according to the following instructions: Fill farmers' SWC options in the second row of column "**B**", in Table A2. First option is the without conservation situation. If there is surface run on effect from up slope fields, add to the selection an infiltration ditch or cut-off drain. One measure is entered at a time for one field.

Figure A2. *Example of farmers identifying fields on the erosion map in Kwalei catchment, Tanzania*

Figure A3. *Soil erosion status map derived from farmers' erosion indicator mapping in Kwalei catchment*

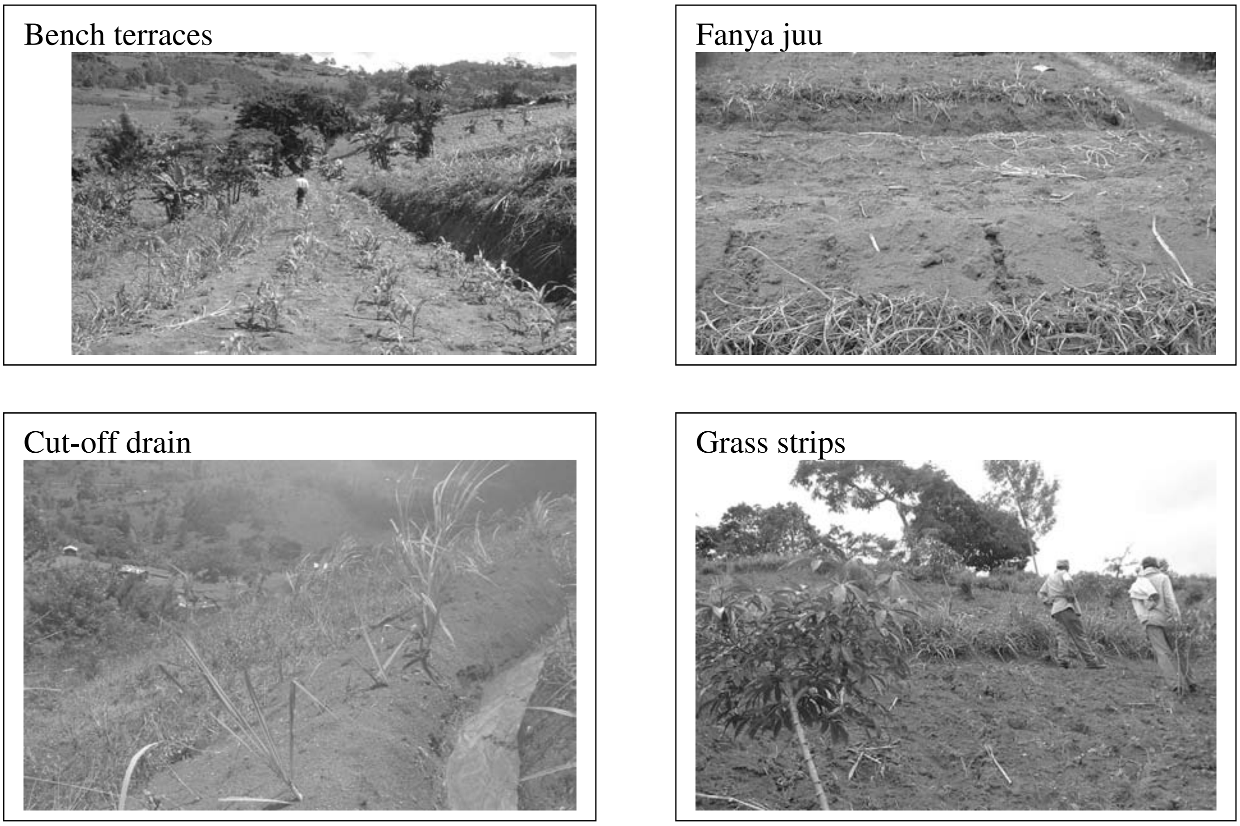

Figure A4. *Important SWC measures used in East African highlands*

Table A1. *Guidelines for selecting SWC options based on bio-physical situation*

Bio-physical condition	SWC Options	Requirements
Slope and soils		
2< % Slope <12	Mulching, vegetative strips, agroforestry, trashlines, ridges, furrows, contour ploughing, cover crops, deep tillage	Appropriate species and spacing
12<% Slope <35	Fanya juu, terraces, agroforestry	Manure application, stabilize terrace and fanya juu with vegetative strips
35<% Slope <55	Bench terrace, Fanya juu	Manure application, stabilize with grass strips, cut-off drain, high value crops
% Slope > 55	Tree planting, perennial crops	Cut-off drain
Very long slope	Cut-off drain,	Availability of water way for discharge
Shallow soils	Fanya juu	Clean the trench after each rainy season
Water		
Need protection from water outside the farm	Cut off drain	Availability of water way for discharge
Need to maintain or improve soil moisture	Infiltration ditches, Bench terrace	Deep soil, high value crops
No place to discharge water	Retention ditch	Clean the trench after each rainy season
Field on upper part of catchment	Cut-off drain, infiltration ditch, agroforestry	Check conditions under individual measure
Need to irrigate on steep slopes	Bench terraces	High value crops
Others		
Need fodder for livestock	Vegetative strips	Appropriate species and spacing

Table A2. *Labour inputs and costs of selected SWC measure*

Farmer name:	…………	**Location:**	………………..
Field concerned:	…………		
SWC measure:	e.g. Bench terraces	**Field location**	Upper, middle or lower
Area (in ha)	e.g. 0.30	**Soil type**	Stable or unstable
Crop(s) before	e.g. Maize	**Slope class**	Gentle, mod, strong, steep, vs
Crop(s) with SWC	e.g. Maize & fodder	**Erosion class**	High, moderate or low

Operation **A**		Mandays required (LD) **B**			Opportunity costs **C**	Labour costs (Tsh) **D**		
	Year	Without	SWC	Cutoff d*	TSh/LD	Without	SWC	Cutoff d*
Investment								
Layout	0							
Construction	0							
Stabilisation	0							
Total labour investment	0					D1	D1	(D1)
Maintenance	1-15					D2	D2	(D2)
Production								
Land prep.	1-15							
Manure applic.	1-15							
Planting	1-15							
Weeding	1-15							
Fertiliser appl	1-15							
Spraying	1-15							
Harvest	1-15							
Transport	1-15							
Total labour for prod.	1-15					D3	D3	(D3)

* Information on cutoff drains only to be given, when these are required

Step 2: Determination of socio-economic situation

Aim: To understand the socio-economic characteristics of the respective farmer(s).

Expected output: List of socio-economic characteristics of the farmer.

Activities

During a meeting with farmers, the extension staff leads the discussion that should generate socio-economic characteristics for each individual farmer or group of farmers with similar characteristics. These characteristics include sources and size of labour force for implementing SWC measures, activities that are to be foregone for SWC measures and earning from off-farm activities. This information will assist the extension staff to determine the opportunity costs of labour.

Other important information will be the time horizon over which to analyse the costs and benefits of SWC measures. Use the information provided by the farmer to determine the opportunity costs of labour as follows:

- If the farmer intends to use hired labour, the opportunity cost will be the prevailing wage rate.
- If family labour will be used the opportunity cost is the foregone income from doing other activities.
- If the farmer has off-farm activities the opportunity costs of labour is the daily earning from the off-farm activities (See box 1).

➢ Fill the corresponding opportunity cost of labour in Table A2 column "**C**"

Box 1: Opportunity costs of labour
When asked why he has not been able to finish the construction of bench terraces in his one hectare farm, Mr. Shetoe responded " I do not have enough time because every working day I have to go to Herkulu estate where I work and earn US $1.2 per day" This is the opportunity cost of labour for Mr. Shetoe.

Figure A5. *Example of group of farmers in Kwalei catchment discussing SWC options and the social and economic situations.*

Step 3: Identification and quantification of costs.

Aim: To identify and quantify all the costs (in monetary terms) to be incurred in implementing the selected SWC measure(s).

Expected outputs: All cost (in monetary terms) in implementing SWC measure.

Activities

In a participatory way, the extension staff, village technicians and farmer(s) discuss all the operations that are required in implementing the selected SWC option(s). After an agreement on the operations, they will first enlist all labour required for these operations.

The extension staff will make use of the general information on labour inputs from the PRA and make necessary corrections according to the specific situation of the farmer. On the basis of the respective operations, the type and quantity of all the equipment and materials that are required in each operation is subsequently discussed. This will differ according to the resources available to each farmer or group of farmers, therefore farmers should take a lead in this part of the discussion. The corresponding prices at the selling point for the equipment and materials should also be identified at this step. The extension staff should check with farmers during this discussion if the price list from the PRA is still valid otherwise make an adjustment accordingly.

The last part of this step is to convert all costs items into monetary value. This is also achieved through discussion where the extension staff led the farmers and village technicians to convert the cost items into monetary values by multiplying the cost items in quantitative terms by their corresponding market prices.

Labour costs

In case of labour, labour cost is the product of the number of labour days (LD) required for particular operation and the opportunity costs of labour for the respective farmer group. One labour day refers to the total number of hours in a day a farmer can work in the farm. An opportunity cost of labour refers to the amount in monetary value a farmer would be paid by doing other activities. All costs are added to obtain total costs for investment, production and maintenance. After each discussion, the extension staff or any lead person should fill the required information in Table A.2 as follows:

- List in Table A2 column "**A**", all the operations required for: (i) establishment (ii) maintenance and (iii) production of each conservation measure selected by the farmer (s). Fill in column "**B**", the number of labour days required for each operation under the respective SWC option. Use Figure A6 and Table A3 as guidelines, if the situation and the selected SWC measures are completely different consult the nearest extension office, research station or any knowledgeable persons with regards to the respective measure. Compute the labour cost for each operation as the product of number of labour days and the opportunity costs per labour day (LD) (See Box 2). Add the labour costs in column "**D**" to obtain the total labour costs. The lead person should make sure that farmers understand the results at each step.

Box 2: Calculation of labour costs (Table A2)
Labour costs (D) = Labour days (B) x Opportunity cost per labour day (D)

Table A3. *Example of average labour requirements for establishment and production of three SWC measures in Kwalei, West Usambara Tanzania.*

Item	Unit	Bench terraces	Fanya juu	Grass strips	Without conservation
Layout	m/LD†	100	100	100	0
Construction	m/LD	8	13	100	0
Plant grasses	m/LD	200	200	250	0
Land preparation	LD/ha	20	20	25	30
Manuring	LD/ha	15	15	15	16
Plant-maize	LD/ha	15	15	16	17
Plant beans	LD/ha	12	12	13	14
Weeding	LD/ha	10	10	12	15
Fertilization	LD/ha	12	12	13	14
Harvest-maize	LD/ha	15	15	16	20
Harvest beans	LD/ha	9	9	10	14
Harvest fodder	LD/m	0.1	0.1	0.1	0

†LD = Labour day = 5-8 Working hours

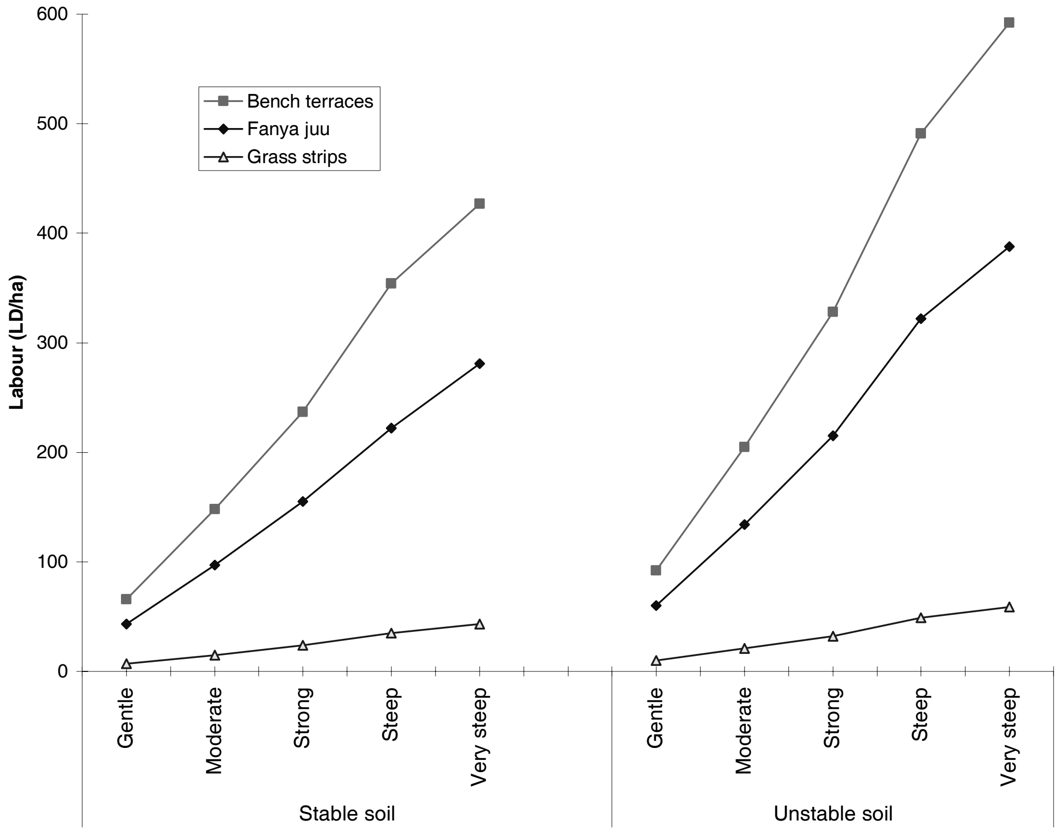

Figure A6. *Average labour requirements for establishing bench terraces, fanya juu and grass strips on stable soil.*
Slope classes (%): Gentle = 5-12, Moderate = 13-25, Strong = 26-35, Steep = 36-45, Very steep = >55

Material and equipment costs

- List in Table A4 column "**F**" all the equipment and materials to be used in each of the operations mentioned in column "**E**". Fill in column "**G**" the unit of measurement for each equipment. Fill in column "**H**" the quantity of equipment or materials required for each corresponding operation and SWC option. Fill in column "**I**" the unit price for each equipment/material. (Use the prevailing market prices at the point where farmer(s) will buy the equipment/materials). Compute the equipment/materials costs as the product of the quantity of each type of equipment/material (Box 3)

Box 3: Calculation of equipment and material costs (Table A3) Equipment costs (F) = Quantity (H) x Unit price (I).

- Add all equipment and material costs in column "**J**" to obtain total equipment and material costs. Repeat computation of equipment and material costs for at least five years.

Table A3. *Equipment and material inputs and costs of SWC measure*

Farmer name:	…………..	**Location:**	……………
Field concerned	…………..		
SWC measure:	e.g. Bench terraces	**Field location**	Upper, middle or lower part
Area (in ha)	e.g. 0.30	**Soil type**	Stable or unstable
Crop(s) before	e.g. Maize	**Slope class:**	Gentle, mod, strong, steep vs.
Crop(s) with SWC	e.g. Maize	**Erosion class**	High, moderate or low

Operation E	**Material type** F	**Unit** G	**Quantity** H			**Unit price** I	**Equipm & mat. costs (Tsh)** J		
			Without	SWC	Cutoff d*	TSh/pc	Without	SWC	Cutoff d*
Investment									
Layout	e.g. line level e.g. poles								
Construction	e.g. spades								
Stabilisation									
Total investm. labour input	(Year 0)						J1	J1	(J1)
Maintenance	(Year 1-15) e.g. panga						J2	J2	(J2)
Production	**(Year 1-15)**								
Land prep.	e.g. hand hoe								
Manure applic.	Manure								
Planting	Seeds								
Weeding									
Fertiliser appl	Fertilisers								
Spraying									
Harvest									
Transport									
Total annual Mat. input							J3	J3	(J3)

* Information on cutoff drains only to be given, when these are required

Step 4: Identification and quantification of expected benefits

Aim: To identify and quantify in monetary terms all benefits expected from the respective SWC measures.

Expected output: List of all expected benefits from SWC measure and their corresponding monetary values.

Activities

Benefits are all gains in current and future production caused by applying certain SWC measures. They may include yield increases, fodder production, poles, fuel wood, increase in land value etc. These benefits will depend on the type of crop and the farming system practiced by the farmer. In this step, the extension staff leads the farmers on discussion of the expected benefits of the selected SWC options. Farmers who have implemented SWC measures before, also share their experiences on the benefits. To make farmers understand, the extension staff can use some examples of benefits from other places (Figure A7). The benefits for particular SWC measures selected by the farmer (s) are then quantified. This is achieved by attaching quantitative values to the measurable parameters for each of the benefit item agreed during the discussion above (e.g. yield in 10 bags, fodder production in 50 kg, etc.). The extension staff will lead in this quantification based on the physical information such as yield levels and erosion status from the soil erosion map and the basic input data (data obtained from PRA) on the impacts of SWC measures. Adjustments can be made based on professional experiences, information from experiences of farmers and the guidelines provided in the tool manual. All the benefits are then added up to obtain total production value (gross benefits) for each SWC option and the without SWC situation. The extension staff or any lead person should fill the results of the discussion in Table A4 following the guidelines below:

- List in column "**K**" of Table A4 all the expected benefits from the respective SWC measure. Fill in column "**I**" the common unit of measurements for each benefit (Local units can be used). Fill in column "**M**" the benefits in quantitative term for each SWC measure. Fill in column "**N**" the unit price for each benefit. Compute the revenue for each benefit and the respective SWC measure as the product of quantity and the unit prices (See Box 4).

Box 4: Calculation of revenues (Table A4)
Revenues (O) = Quantity (M) x Unit price (N)

Add all the production values (revenues) in column "**O**" to obtain the total production value (Gross benefit) for each SWC measure and for the without conservation. Repeat step 4 for all number of years under consideration.

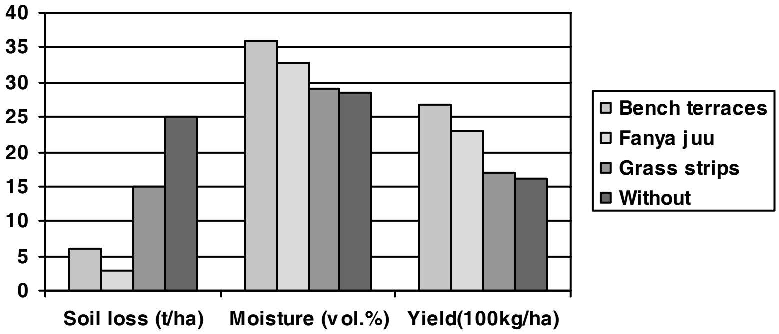

Figure A7. *Example of benefits of soil and water conservation in terms of reduction of soil loss, retention of soil moisture and increase in maize yields. Data from Kwalei catchment, Tanzania.*

Table A4. *Production and production value with/without SWC measure*

Farmer name:	………	**Location:**	………..
Field concerned	………		
SWC measure:	e.g. Bench terraces	**Field location**	Upper, middle or lower part
Area (in ha)	e.g. 0.30	**Soil type**	Stable or unstable
Crop(s) before	e.g. Maize	**Slope class:**	Gentle, mod, strong, steep, vs.
Crop(s) with SWC	e.g. Maize, fodder	**Erosion class**	High, moderate or low

Production **K**	Unit **L**	Year	Quantity **M** Without	SWC		Unit price **N** TSh/unit	Production value (Tsh) **O** Without	SWC	In case No price
Crop(s)									
Maize	Bag	1							
	Bag	2							
	Bag	3-15							
Beans	Bag	1							
	Bag	2							
	Bag	3-15							
Fodder	Bundle	1							
	Bundle	2							
	Bundle	3-15							
Wood	Bundle	1							
	Bundle	2							
	Bundle	3-15							
Other									
Total prod. value		1					O1	O1	PM
		2					O2	O2	PM
		3-15					O3	O3	PM

Step 5: Determination of the net benefits and cash flow

Aim: To identify the net gains (benefits) by implementing certain soil and water conservation measure.

Expected output: Net benefits by implementing certain SWC measure in comparisons with the without soil and water conservation situation.

Activities

At this step, the extension staff or the village technician (if already trained) makes the calculations but ensures that farmers can understand the results. The steps involved in this calculations are: first is to determine the net revenue by calculating the differences between total production values (output from step 4) and the total costs (output from step 3) for each SWC measure and the without conservation situation. Secondly, is to calculate the differences between net revenue for each SWC measure and the without SWC. The difference in net revenue between SWC measure and the without conservation situation is the net gain by implementing a certain SWC measure. The net benefit is calculated for at least five years to get the cash flow trend with time.

Specific instructions for calculations in this step are for the extension staff or any lead person to transfer the required information from Tables A2, A3 and A4 to the cash flow analysis table (Table A7)

Step 6: Discounting the future costs and benefits to the present

Aim: To convert the costs and benefits in future to present values.

Expected outputs: Present value of future net benefits of SWC.

Activities

Most of the costs of SWC measures have to be made in first year(s), while most the benefits occur in the far future. The stream of these future net benefits have to be compared with the present costs, whereby discounting is applied. The rationale behind discounting is explained to farmers, by asking them whether they would prefer to receive for example Tsh 900 now or Tsh 1000 next year (time preference of money), and by indicating that they could investment that Tsh 900, or put it in the bank, to obtain a higher amount next year (opportunity costs of capital).

Evaluation criterion in this case is the net present value (NPV), which is the current value of streams of present and future costs and benefits. It is obtained as the product of net benefit and the appropriate discount factor for all years.

- Extension staff or village technician performs the calculation; first by selecting the appropriate discount rate that is applicable to the area (Table A6) and then calculating the product of the discount factor and the annual net benefit (cash flow) for each SWC measure for time horizon under consideration (Box 5, Table A7). The determination of internal rate of return (IRR) is optional, when computer is used. The IRR shows the rate at which the project is returning the capital used for investment.

Box 5: Calculation of net present value (Discounted cash flow) (Table A7)
Net Present Value (Discounted cash flow) = Net benefit (cash flow) x discount factor.

Table A6. *Discount factors for 15 years at three discount rates*

Time (Years)	Discount (interest) rate		
	DR = 8%	DR =10%	DR =13%
0	1.00	1.00	1.00
1	0.93	0.91	0.89
2	0.86	0.83	0.78
3	0.80	0.75	0.69
4	0.74	0.68	0.61
5	0.68	0.62	0.54
6	0.63	0.56	0.48
7	0.58	0.51	0.43
8	0.54	0.47	0.38
9	0.50	0.42	0.33
10	0.46	0.39	0.29
11	0.43	0.36	0.26
12	0.40	0.32	0.23
13	0.37	0.29	0.20
14	0.34	0.26	0.18
15	0.32	0.24	0.16

Table A7. *Cash flow and financial results for SWC measure*

Farmer name:	……………	**Location:**	……………….
Field concerned	……………		
SWC measure:	Bench terraces	**Field location**	Upper, middle or lower part
Area (in ha)	e.g. 0.30	**Soil type**	Stable or unstable
Crop(s) before	e.g. Maize	**Slope class:**	Gentle, mod., strong, steep, very steep
Crop(s) with SWC	Maize, fodder	**Erosion class**	High, moderate or low

Year	**Labour costs**		**Material costs**		**Production value**		**Cash flow** O - D - J	**Discount rate**	**Discounted cash flow**
	Without	With	Without	With	Without	With	With-W'out	e.g. 10%	
0	D1	D1	J1	J1			-D1-J1	1	
1	D(2+3)	D(2+3)	J(2+3)	J(2+3)	O1	O1	O1-D-J $^{2+3}$	0.91	
2	D(2+3)	D(2+3)	J(2+3)	J(2+3)	O2	O2	Etc.	0.83	
3	D(2+3)	D(2+3)	J(2+3)	J(2+3)	O3	O3		0.75	
4	D(2+3)	D(2+3)	J(2+3)	J(2+3)	O3	O3		0.68	
5	D(2+3)	D(2+3)	J(2+3)	J(2+3)	O3	O3		0.62	
6	D(2+3)	D(2+3)	J(2+3)	J(2+3)	O3	O3		0.56	
7	D(2+3)	D(2+3)	J(2+3)	J(2+3)	O3	O3		0.51	
8	D(2+3)	D(2+3)	J(2+3)	J(2+3)	O3	O3		0.47	
9	D(2+3)	D(2+3)	J(2+3)	J(2+3)	O3	O3		0.42	
10	D(2+3)	D(2+3)	J(2+3)	J(2+3)	O3	O3		0.39	
11	D(2+3)	D(2+3)	J(2+3)	J(2+3)	O3	O3		0.36	
12	D(2+3)	D(2+3)	J(2+3)	J(2+3)	O3	O3		0.32	
13	D(2+3)	D(2+3)	J(2+3)	J(2+3)	O3	O3		0.29	
14	D(2+3)	D(2+3)	J(2+3)	J(2+3)	O3	O3		0.26	
15	D(2+3)	D(2+3)	J(2+3)	J(2+3)	O3	O3		0.24	
						IRR:		NPV(Tsh *100)	
	EXAMPLE: (in 100 Tsh)								
0	0	600	0	150			-750	1	-750
1	100	120	40	70	300	250	-100	0.91	-91
2	100	120	40	70	300	400	50	0.83	42
3	100	120	40	70	300	500	150	0.75	113
4	100	120	40	70	300	500	150	0.68	102
5	100	120	40	70	300	500	150	0.62	93
6	100	120	40	70	300	500	150	0.56	84
7	100	120	40	70	300	500	150	0.51	77
8	100	120	40	70	300	500	150	0.47	71
9	100	120	40	70	300	500	150	0.42	63
10	100	120	40	70	300	500	150	0.39	59
11	100	120	40	70	300	500	150	0.36	54
12	100	120	40	70	300	500	150	0.32	48
13	100	120	40	70	300	500	150	0.29	44
14	100	120	40	70	300	500	150	0.26	39
15	100	120	40	70	300	500	150	0.24	36
						IRR (%)	11.4%	NPV (Tsh100)	81

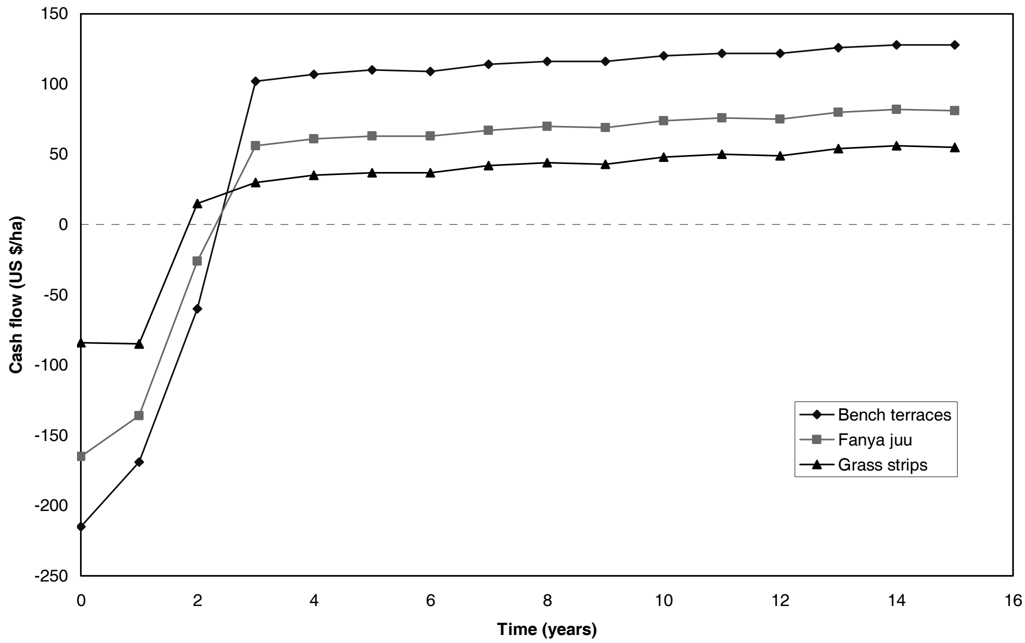

Figure A8. *Cash flow of three SWC measures for a maize and beans farmer with opportunity costs of labour of 1US \$ per labour day on moderate slope and stable soil*

Step 7: Feedback and discussion of the results.

Aim: To discuss and make the farmer understand the meaning of cash flow and the net present value (discounted cash flow).

Expected output: Farmer understands the short and long term benefits of the respective SWC measures.

Activities

The extension staff leads the discussion by explaining to the farmer (s) the meaning of cash flow and net present values (discounted cash flow). The extension staff may use pictorial presentation in the form of chart or graphs to make sure that farmers understand. Examples of these graphs are Figures A8 and A9.

The cash flow figure (A8) shows the farmer the efforts he has to make, in terms of labour and material inputs, in the early years before he can expect some steady net benefits. And the results of the net present value calculations (Figure A9) shows the farmers under which conditions of soil type and slope the respective SWC measures are financially attractive. It appears among others in Figure A9 that the three measures are never attractive at very steep slopes, and that these are seldom attractive at higher opportunity costs of labour. If farmers are in particular interested to know what crop yield increase they should get at least with the SWC measures to make it financially viable, a breakeven analysis can also be undertaken, setting the NPV or IRR at certain values and calculating the required yield increase under the specific conditions. And a sensitivity analysis could be undertaken to see what the effects are of some changes in assumptions.

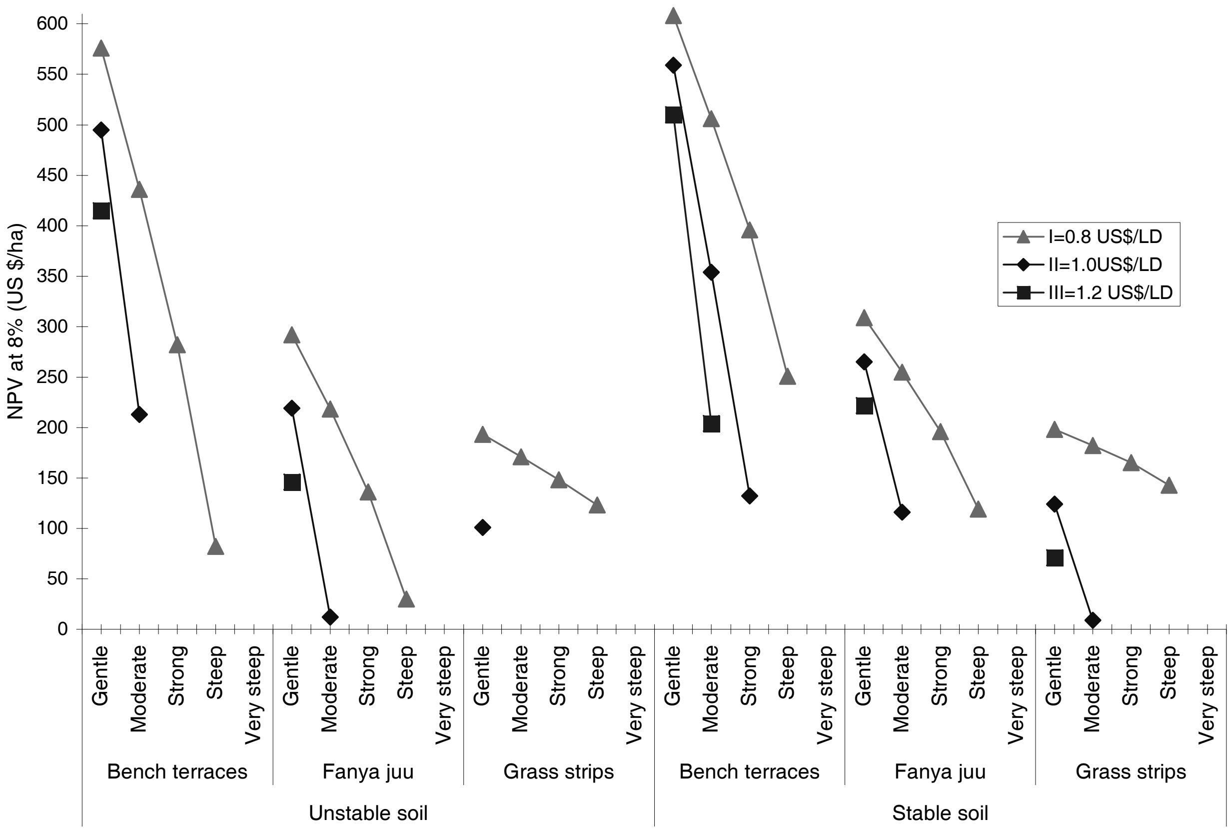

Figure A9. *Example of long term (15 years) benefits (NPV at 8%) of three SWC measures on unstable and stable soils, five slope classes and farmers with three opportunity costs of labour . Data from West Usambara mountains, Tanzania*

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Step 8: Farmer(s) make final decision on the SWC to implement

Aim:	To enable farmer understand and make an informed decision on which SWC measure to implement.
Expected output:	Farmers final decision on SWC measure to implement.

Activity

In this step, the extension staff presents the results for each SWC measure selected by the respective farmer or group of farmers. The implications of the results are discussed until farmer(s) make an informed final decision on which SWC measure(s) to implement. After discussions with an individual farmer, the extension officer will organise a community meeting where all farmers in the catchment attend. In this community meeting, the extension officer shows the soil erosion map developed earlier using the participatory soil erosion mapping tool to remind farmers of the erosion situation in the catchment. Then the financial analysis results for individual farmer are presented pointing to the specific fields on the map. With evidences from the financial analysis, attention in this discussion should be focused to the extra costs that an individual farmer has to incur because of the run-on from the upslope field or from public areas. This is discussed until farmers reach an agreement on what actions to be taken.

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Curriculum vitae

Albino J.M.Tenge is an Agricultural engineer. He was born on 29 December 1964 in Wasa Iringa, Tanzania. After 7 years of primary school and 4 years of secondary school at Wasa and Tosamaganga respectively he obtained an advanced secondary school certificate in Physics, Mathematics and Chemistry in 1986 at Tanga Technical School. In 1987, he entered the Sokoine University of Agriculture and obtained a Bachelor of Science degree in Agricultural engineering in 1991. The Ministry of Agriculture employed him in 1991 as Agricultural Researcher at Mlingano Agricultural Research Institute in Tanga. As a researcher in Soil and water conservation, he was responsible for design and execution of research experiments for appraisal and evaluation of SWC measures. He obtained in 1995 a Master of Science (M.Sc.) degree in Soil and water conservation from the Ohio State University in USA. The title of his thesis was "Erosion effects on soil moisture and temperature and crop yields on eastern Usambara uplands, Tanzania. He continued to work as agricultural researcher until 2001 when he was admitted to the PhD program of Erosion and Soil & Water Conservation Group, Department of Environmental Sciences, Wageningen University and Research Centre in The Netherlands. Between 2001 and 2004, he conducted the research leading to this PhD thesis. The research involved physical experiments to assess the effectiveness of SWC measures and household surveys to understand the social and economic factors for adoption of SWC measures. During this research period, he also supervised M.Sc. students, trained local assistants and presented research results at both international and national conferences. At this moment, he is still working as a researcher with the Agricultural Research Institute, Malignant, Tanzania. His contact address is atenge@hotmail.com

PE&RC PhD Education Statement Form

With the educational activities listed below the PhD candidate has complied with the educational requirements set by the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) which comprises of a minimum total of 32 ECTS (= 22 weeks of activities)

Review of literature (ECTS 4)

- ARI-Mlingano, Tanzania (2000)
- Environmental Sciences - ESWC (2001)

Writing of project proposal (ECTS 5)

- Economic evaluation of soil and water conservation in West Usambara highlands, Tanzania (2000-2001)

Post-Graduate Courses (ECTS 4)

- Operational tools for regional land use analysis (2001)
- Geographic Information System (2002)

Deficiency, Refresh, Brush-up and General courses (ECTS 6)

- Social and economic aspecsts of erosion and water conservation (2000)
- Processes and models in erosion and soil and water conservation (2000)

PhD discussion groups (ECTS 4)

- Internal Program Review-Soils, Tanzania (2001)
- PhD discussion group 7- WUR (2004)

PE&RC annual meetings, seminars and introduction days (ECTS 1.25)

- Ethics in Science (2002)
- Seminar series ESW: Sustainable land management (2004)

International symposia, workshops and conferences (ECTS 5)

- East African Soil Science Annual Conference (Uganda, 2002)
- Quantification of soil erosion and sedimentation indicators in Central Highlands, Kenya (2004)
- Economic Analysis of Soil and Water Conservation in West Usambara Highlands, Tanzania (2004)

Laboratory training and working visits (ECTS 3)

- Soil Physical and Chemical Properties. National Soils Laboratory Mlingano (Tanzania, 2001-2003)